RESEARCHES

ON

SOLAR PHYSICS.

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FIRST SERIES.

ON THE NATURE OF SUN-SPOTS.

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RESEARCHES ON SOLAR PHYSICS.

FIRST SERIES.—ON THE NATURE OF SUN-SPOTS.

1. There is a marked difference between our luminary and our satellite, as far as regards our knowledge of their physical aspect and constitution. Many parts of our own globe are not so well known, or so correctly mapped, as certain regions in the moon; and could we imagine an observer transported into the neighbourhood of Tycho or Copernicus, he would probably be better prepared for the appearance presented to him, than he would be if placed suddenly in equatorial Africa or central Australia. But with regard to the sun the case is very different; for although the progress of science has enabled us to detect the presence of certain familiar substances in the atmosphere of our luminary, it has hitherto only shrouded in deeper mystery than ever the origin of that wonderful outpouring of light and heat which is the sun's most prominent characteristic, and to this very day it has not been finally decided whether this luminosity proceeds from the sun's solid body or from an envelope which surrounds it. Indeed so strange and so unaccountable are many of the features presented to us, not only by our own sun, but by many of the stars, that it has even been conjectured that these bodies exhibit instances of the operation of some force of the nature of which we are yet ignorant. If we accept this view of the case, the study of our luminary becomes one of very great importance, but one in which we must be very careful to be guided by observation alone. We must obtain numerous and accurate representations of the sun's surface, and study these carefully and minutely, before we attempt to generalize.

§ I. *Methods of Observation.*

2. There are two methods of accomplishing this.

(1.) Eye-observations of the sun's surface may be made by means of a telescope, and the appearance carefully mapped by the observer.

(2.) Or we may call to our aid that art which has already proved of signal service in many branches of science, and, by means of photography, obtain autographs of our luminary, which we may measure and examine carefully at our leisure.

Each of these has its advocates, but it is not our design to discuss the comparative merits of the two methods; on the contrary, as each has its own special advantages, we are willing to adopt them both, and to avail ourselves of all those materials which our own observations or the kindness of friends may have put into our hands.

§ II. *Historical Sketch.*

3. The most important knowledge which we possess regarding the physical appearance and structure of our luminary is derived from the following sources.

4. *Sun's Rotation.*—We are, in the first place, indebted to GALILEO, if not for the first discovery of sun-spots, at least for the first attempt to ascertain through their means the period of rotation of our luminary.

5. *Nature of Sun-spots.*—The next great advance in Solar Physics is due to ALEXANDER WILSON, Professor of Astronomy at Glasgow, who in 1773 communicated a paper to the Royal Society, describing certain phenomena with regard to spots, which, in his opinion and in that of many others, appear to indicate that spots are cavities in a luminous photosphere which surrounds the sun.

The accuracy of this conclusion has recently been questioned; but whatever may be said regarding the theory, there can be no doubt regarding the importance of the fact which was first revealed by WILSON.

6. *Their Periodicity.*—The next step is due to Hofrath SCHWABE, of Dessau, who has shown, as the result of nearly forty years' laborious observations, that the number of spots which break out on the sun's surface is not the same from year to year, but has a maximum about every ten years—a remark which led General SABINE to observe that the various epochs of maximum spot-frequency were also those of maximum magnetic disturbance in our own globe.

7. *Their proper Motion, &c.*—CARRINGTON is the next observer who has greatly extended our knowledge of this subject. In a large and most remarkable work recently published, and containing the result of many years' observation, he has shown that sun-spots have a proper motion of their own, those near the solar equator moving faster than those near the poles; and he has also made interesting remarks on the distribution of spots in solar latitude for different years. In addition to these new facts, he has furnished us with very accurate data regarding the sun's rotation.

8. *Gradations in their Luminosity.*—We ought also to mention the discovery by DAWES, that what is regarded as the umbra of a spot consists in many cases of two well-defined and separate parts *, the exterior part being less luminous than the interior; so that we have often connected with the same phenomenon not less than five degrees of luminosity: these are—

(1.) The faculæ.
(2.) The ordinary photosphere.
(3.) The penumbra.
(4.) The borders of the umbra.
(5.) The very dark central nucleus.

Mr. DAWES's discoveries are mainly due to his employing, with an eye-piece of his

* In some cases, however, it is fair to assume that the appearance of lighter portions of the umbra may be caused by the floating across of portions of the brighter part of the sun's surface.

own invention, the full aperture of the telescope; but it is necessary to recall the fact that Sir William Herschel, in earlier times, was fully aware of the importance of not contracting the aperture of the objective. Moreover we must not forget that Sir W. Herschel contributed to solar physics a theory which still holds its ground.

9. *Red Flames.*—But there is another phenomenon connected with our luminary, not less curious than solar spots. We allude to the red flames, or protuberances which are seen to surround the sun's disk on the occasion of a total eclipse. Airy and Arago were the first to conjecture that these belonged to the sun. In the total eclipse of 1851, the former of these observers, by combining his observations with those of O. Struve, showed it to be probable that these flames do not change *during the moon's motion.* Great credit is also due to this observer for organizing the Spanish expedition of 1860; and it was here that Mr. De la Rue, by means of the Kew heliograph, set the matter completely at rest. Mr. De la Rue, from the pictures which he obtained, was able to show that the flames only change apparently, not really, by the moon's motion over them, that is, by covering one portion and disclosing another, and do not otherwise undergo any alteration; so that when the clock of his instrument was adjusted to the sun's motion, that portion of the flames not covered by the moon stood still. He also showed that the angular motion of the red flames, with respect to the moon, corresponds to the theory of their fixation in the sun.

These results were verified by Secchi, who also obtained photographs of the same phenomenon, which were compared in Rome by Mr. De la Rue and Father Secchi with Mr. De la Rue's photographs. The forms of the red prominences were found identical in both, so that no change occurs in their form during an interval much longer than the duration of totality observations in a solar eclipse.

10. *Willow-leaves.*—We may be allowed to mention here that very lately Mr. James Nasmyth, during the course of his observations of the sun's surface, has come to the conclusion that, when the circumstances of observation are very favourable, the whole surface will be found to be composed of separate luminous bodies, of a great similarity of figure, interlacing one another; and he has given the name of *willow-leaves* to these appearances. The existence of these is still disputed; but some of our best observers in this country have seen them under very favourable atmospheric conditions, and they have been seen more frequently by Secchi and other Italian observers.

11. *Other observations of the Sun's surface.*—Chacornac, the eminent French observer, has noticed a behaviour of those portions of the Sun's surface around a spot which seems to imply the existence of a downward current. More recently Lockyer, in this country, has made a very important observation of a similar kind. A tongue of faculous matter projecting over a spot was observed to lose its brilliancy very rapidly, so as ultimately to seem less brilliant than any portion of the penumbra. At the same time it seemed to be "giving out," as it were, at its end, and a portion of the umbra between it and the penumbra appeared to be veiled with a stratus cloud evolved out of it.

We ought likewise to mention the excellent and numerous observations of Pastorff,

preserved in the library of the Royal Astronomical Society, also those of Captain SHEA, both of which the Council of that Society have placed at our disposal. Professor WOLF, of Zurich, has collected data for establishing the periodicity of Sun-spots before the commencement of SCHWABE's observations. Also the Rev. J. HOWLETT, in this country, has produced a large series of drawings of the Sun's surface on a large scale, and of exquisite delicacy of delineation, which will no doubt prove of much value; and, finally, this field of research is one that has been occupied by many observers in all parts of the world, so that we may hope with some confidence for a speedy increase of our knowledge in this very important branch of physical astronomy.

12. *Composition of Solar Atmosphere.*—Before concluding this very brief historical sketch, we ought to allude to the discovery of KIRCHHOFF and BUNSEN, who, by means of the spectroscope, have proved that many familiar substances, such as sodium, iron, magnesium, &c., exist in the atmosphere of our luminary in the state of vapour.

§ III. *Materials at the Authors' disposal.*

13. We now proceed to describe what materials we have at our disposal for the purpose of these investigations.

In the first place, Mr. CARRINGTON has very kindly put into our hands all his original drawings of sun-spots. These extend from November 1853 to March 1861; and in them the sun's disk is represented on the scale of one foot in diameter, while, for each spot, the apparent position on the disk, as well as the proportion in size to the whole surface, is accurately delineated. We hope, in our investigations (as far as spots are concerned), to make much use of these pictures by CARRINGTON; they do not, however, afford us any information with regard to faculæ.

More recently we have received into our hands the magnificent collection of drawings of the sun made by Hofrath SCHWABE, of Dessau, during the course of about forty years, —this distinguished observer having generously placed these in the possession of the Royal Astronomical Society, for the use in the meantime of the Kew Observatory.

Our materials are, moreover, derived from the pictures taken by the Kew heliograph. This instrument, with its various adjustments, has already been described by Mr. DE LA RUE in the Bakerian Lecture for 1862; and it is therefore unnecessary to give a further description of it here. A few pictures were taken by this instrument at the Kew Observatory in the years 1858 and 1859. In July 1860 it was in Spain, doing service at the total eclipse. In 1861 a few pictures were taken at Kew; while, from February 1862 to February 1863, the instrument was in continuous operation at Mr. DE LA RUE's private observatory at Cranford; and from May 1863 until the present date it has been in continuous operation at Kew, under Mr. DE LA RUE's superintendence. It is right to mention that for the perfection of these pictures much credit is due to the late Mr. WELSH and to Mr. BECKLEY, under whose immediate supervision the pictures at Kew have been taken by a qualified assistant, Miss BECKLEY.

§ IV. *Method of Reduction.*

14. These are the materials at our disposal; and it may here be desirable to state in a few words the principle by which we shall be guided in our reduction of these materials. In the progress of this branch of knowledge, observers have been led to recognize certain laws, which represent the average behaviour of sun-spots; but to each of these laws there are individual exceptions. In this state of things it is probable that our knowledge of the subject will ultimately be advanced, not only by a study of those groups which behave in a normal manner, but also by a study of those which are exceptions in their behaviour to the general rule; and on this account it has been thought desirable to publish the results in such a way that any one may be able as far as possible to study the appearance and behaviour, in fact, the whole history of any one group. Setting aside, in the meantime, SCHWABE's drawings for future consideration, we propose to adopt the following plan of publication for CARRINGTON's pictures and for those of the Kew heliograph. In discussing CARRINGTON's observations, we shall of course adhere to the numbering of his different groups which he has given; and as he has also exhibited a pictorial history of each of these groups in his published volume, in which the spots are represented, though on a smaller scale than in his original drawings, all that is necessary on our part is to accompany any remark we may make regarding one of CARRINGTON's groups with the number of that group as given by him.

Next with regard to the Kew pictures. Beginning with the first picture in 1858, it is our intention to number each group of spots in the same manner as CARRINGTON, calling the first No. 1, and so on upwards to the present date. It is also our intention ultimately to publish carefully copied representations of each of the Kew groups; but these are not yet ready. We think it well, however, to give at once the numbers of the groups, coupled with the dates at which each group was first seen, and also to make use of these numbers in our present paper in anticipation of the forthcoming pictorial representations, which, when they appear, will enable our readers to judge for themselves of the truth of our remarks.

15. A Table giving the number of the group, with the date of its first appearance, has also this advantage. It has been strongly urged upon the writers by General SABINE, that it would be of great importance to go on with Hofrath SCHWABE's method of numbering groups, since it is not to expected that he will continue for many more years to be a constant observer of the sun's disk. And although it is likely that, when Hofrath SCHWABE's drawings are discontinued, other pictures of a more perfect nature, such as those at Kew, will be regularly taken, yet it would obviously be a great pity if the new system of observation, while doing something more, should not at the same time continue, without a break, the very same work which Hofrath SCHWABE has so successfully begun, thereby obtaining for science a catalogue of the number of groups for each year, uninterrupted by the discontinuance of this distinguished observer.

16. In the following Table we have the number of each Kew group, and the date at which it was first observed.

Table I.

Giving the number and date of first appearance of all groups of Sun-spots shown by the Photographs of the Sun preserved at Kew, from March 11, 1858, to December 31, 1864.

No. of group.	Date of its first appearance.	
	1858.	
1.	March	11.
2.	„	„
3.	„	„
4.	„	„
5.	„	15.
6.	„	23.
7.	„	„
8.	„	„
9.	„	„
10.	„	„
11.	„	27.
12.	„	„
13.	April	21.
14.	„	„
15.	„	„
16.	„	„
17.	„	„
18.	„	„
19.	„	„
20.	„	23.
21.	„	„
22.	„	28.
23.	August	24.
24.	„	„
25.	„	„
26.	„	„
27.	„	26.
28.	„	„
29.	„	28.
30.	October	11.
31.	„	„
32.	„	„
33.	„	„
	1859.	
34.	January	26.
35.	„	„
36.	„	„
37.	„	„
38.	„	„
39.	„	28.
40.	„	„
41.	February	19.
42.	„	„
43.	„	„
44.	„	23.
45.	„	19.
46.	„	23.
47.	„	„
48.	„	25.
49.	March	1.

No. of group.	Date of its first appearance.	
	1859.	
50.	March	1.
51.	„	2.
52.	„	„
53.	„	4.
54.	„	10.
55.	„	„
56.	„	„
57.	„	„
58.	„	„
59.	„	4.
60.	„	18.
61.	„	„
62.	„	„
63.	„	„
64.	„	„
65.	„	„
66.	„	21.
67.	„	„
68.	April	1.
69.	„	„
70.	„	„
71.	„	„
72.	„	„
73.	„	3.
74.	„	6.
75.	„	„
76.	„	„
77.	„	7.
78.	„	„
79.	„	„
80.	„	„
81.	„	„
82.	„	11.
83.	„	„
84.	„	„
85.	„	„
86.	„	„
87.	„	21.
88.	„	„
89.	„	„
90.	„	„
91.	„	„
92.	„	„
93.	„	„
94.	„	„
95.	„	„
96.	May	13.
97.	„	„
98.	„	„
99.	„	„

No. of group.	Date of its first appearance.	
	1859.	
100.	May	13.
101.	„	„
102.	„	„
103.	„	„
104.	„	„
105.	„	„
106.	August	25.
107.	„	„
108.	„	„
109.	„	„
110.	„	„
111.	„	„
112.	„	„
113.	„	„
114.	„	„
115.	„	„
116.	„	28.
117.	„	29.
118.	„	30.
119.	„	„
120.	„	31.
121.	September	3.
122.	„	16.
123.	„	„
124.	„	„
125.	„	„
126.	„	„
127.	„	„
128.	„	„
129.	„	„
130.	„	18.
131.	„	19.
132.	„	20.
133.	„	22.
134.	„	„
135.	„	„
136.	„	24.
137.	„	„
138.	„	29.
139.	„	„
140.	„	„
141.	„	„
142.	„	„
143.	„	„
144.	October	2.
145.	„	„
146.	„	„
147.	„	3.
148.	„	4.
149.	November	11.

No. of group.	Date of its first appearance.	
	1859.	
150.	November	11.
151.	„	„
152.	„	„
153.	„	„
154.	„	„
155.	„	„
156.	„	„
157.	„	„
158.	„	„
159.	„	„
	1861.	
160.	June	14.
161.	„	„
162.	„	„
163.	„	„
164.	„	„
165.	„	„
166.	„	„
167.	„	„
168.	„	15.
169.	„	17.
170.	„	„
171.	„	18.
172.	„	20.
173.	„	23.
174.	„	„
175.	„	26.
176.	„	„
177.	„	„
178.	„	„
179.	„	„
180.	„	„
181.	„	„
182.	July	2.
183.	„	„
184.	„	„
185.	„	„
186.	„	„
187.	„	„
188.	„	„
189.	November	7.
190.	„	„
191.	„	„
192.	„	„
193.	„	„
194.	„	„
195.	„	„
196.	„	„
197.	„	11.
198.	„	15.

TABLE I. (*continued*).

No. of group.	Date of its first appearance.	No. of group.	Date of its first appearance.	No. of group.	Date of its first appearance.	No. of group.	Date of its first appearance.
	1861.		1862.		1862.		1862.
199.	November 15.	252.	March 19.	307.	June 18.	362.	August 19.
200.	„ 16.	253.	„ „	308.	„ „	363.	„ „
201.	„ „	254.	„ „	309.	„ 23.	364.	„ 24.
202.	„ „	255.	„ 31.	310.	„ „	365.	„ 26.
203.	„ „	256.	„ „	311.	„ „	366.	„ 28.
204.	„ 23.	257.	April 3.	311*a*.	„ „	367.	„ 29.
205.	„ „	258.	„ „	312.	„ „	368.	September 2.
206.	„ 28.	259.	„ „	313.	„ „	369.	„ „
207.	„ „	260.	„ 12.	314.	„ „	370.	„ „
208.	December 1.	261.	„ 13.	315.	„ „	371.	„ 9.
209.	„ „	262.	„ „	316.	„ „	372.	„ 15.
210.	„ 3.	263.	„ 14.	317.	„ „	373.	„ 16.
211.	„ „	264.	„ 15.	318.	„ 24.	374.	„ „
212.	„ „	265.	„ „	319.	„ 27.	375.	„ 18.
213.	„ 5.	266.	„ 20.	320.	„ „	376.	„ „
214.	„ 9.	267.	„ 21.	321.	July 5.	377.	„ 19.
215.	„ „	268.	„ 23.	322.	„ „	378.	„ 30.
216.	„ 11.	269.	„ 25.	323.	„ „	379.	„ „
217.	„ „	270.	„ 27.	324.	„ „	380.	October 1.
218.	„ 15.	271.	„ „	325.	„ 8.	381.	„ „
219.	„ „	272.	„ 29.	326.	„ „	382.	„ 5.
220.	„ „	273.	„ 30.	327.	„ „	383.	„ „
221.	„ „	274.	May 1.	328.	„ 11.	384.	„ 8.
222.	„ 20.	275.	„ 5.	329.	„ „	385.	„ „
223.	„ „	276.	„ 8.	330.	„ 10.	386.	„ 16.
224.	„ „	277.	„ „	331.	„ 11.	387.	„ „
225.	„ „	278.	„ 10.	332.	„ 16.	388.	„ 17.
	1862.	279.	„ 12.	333.	„ „	389.	„ 21.
226.	February 7.	280.	„ „	334.	„ „	390.	„ 23.
227.	„ „	281.	„ „	335.	„ 17.	391.	„ 24.
228.	„ „	282.	„ 16.	336.	„ 18.	392.	„ 26.
229.	„ „	283.	„ „	337.	„ „	393.	„ „
230.	„ „	284.	„ 17.	338.	„ 20.	394.	November 11.
231.	„ „	285.	„ 22.	339.	„ 21.	395.	„ „
232.	„ „	286.	„ 24.	340.	„ 25.	396.	„ „
233.	„ „	287.	„ „	341.	„ „	397.	„ „
234.	„ 10.	288.	„ „	342.	„ „	398.	„ „
235.	„ „	289.	„ „	343.	„ 27.	399.	„ 12.
235*a*.	„ „	289*a*.	„ 29.	344.	„ 28.	400.	„ 13.
236.	„ 16.	290.	June 1.	345.	„ 27.	401.	„ 17.
237.	„ „	291.	„ „	346.	„ 28.	402.	„ „
238.	„ „	292.	„ „	347.	„ 31.	403.	„ 23.
239.	„ „	293.	„ „	348.	„ „	404.	„ „
240.	„ 20.	294.	„ 2.	349.	„ „	405.	„ „
241.	„ „	295.	„ 4.	350.	August 2.	406.	December 12.
242.	„ 21.	296.	„ 7.	351.	„ „	407.	„ 25.
242*a*.	„ „	297.	„ 8.	352.	„ „	408.	„ „
243.	„ 28.	298.	„ 10.	353.	„ 3.	409.	„ „
244.	„ „	299.	„ „	354.	„ „	410.	„ „
245.	„ „	300.	„ 11.	355.	„ 5.	411.	„ „
246.	„ „	301.	„ „	356.	„ 10.	412.	„ 30.
247.	„ „	302.	„ „	357.	„ 15.	413.	„ „
248.	„ „	303.	„ 13.	358.	„ „	414.	„ „
249.	March 3.	304.	„ 14.	359.	„ „		1863.
250.	„ 5.	305.	„ 15.	360.	„ 18.	415.	January 7.
251.	„ 7.	306.	„ 17.	361.	„ 19.	416.	„ 18.

TABLE I. (*continued*).

No. of group.	Date of its first appearance.		No. of group.	Date of its first appearance.		No. of group.	Date of its first appearance.		No. of group.	Date of its first appearance.	
	1863.			1863.			1864.			1864.	
417.	January	18.	472.	August	10.	527.	January	30.	583.	July	14.
418.	,,	,,	473.	,,	,,	528.	February	1.	584.	,,	21.
419.	,,	20.	474.	,,	12.	529.	,,	4.	585.	,,	,,
420.	,,	25.	475.	,,	17.	530.	,,	6.	586.	August	1.
421.	,,	,,	476.	,,	29.	531.	,,	17.	587.	,,	,,
422.	,,	,,	477.	September	7.	532.	,,	,,	588.	,,	4.
423.	,,	28.	478.	,,	10.	533.	,,	,,	589.	,,	5.
424.	February	8.	479.	,,	,,	534.	,,	,,	590.	,,	6.
425.	,,	,,	480.	,,	22.	535.	March	2.	591.	,,	8.
426.	,,	,,	481.	,,	28.	536.	,,	,,	592.	,,	10.
427.	March	28.	482.	,,	,,	537.	,,	,,	593.	,,	,,
428.	,,	,,	483.	October	5.	538.	,,	,,	594.	,,	,,
429.	,,	,,	484.	,,	13.	539.	,,	,,	595.	,,	18.
430.	April	13.	485.	,,	16.	540.	,,	,,	596.	,,	30.
431.	,,	,,	486.	,,	,,	541.	,,	10.	597.	,,	,,
432.	,,	14.	487.	,,	22.	542.	,,	,,	598.	September	1.
433.	,,	20.	488.	,,	,,	543.	,,	,,	599.	,,	3.
434.	,,	23.	489.	,,	31.	544.	,,	16.	600.	,,	15.
435.	,,	28.	490.	,,	,,	545.	,,	17.	601.	,,	,,
436.	,,	,,	491.	,,	,,	546.	,,	,,	602.	,,	17.
437.	,,	30.	492.	,,	,,	547.	,,	23.	603.	,,	24.
438.	May	2.	493.	November	12.	548.	,,	,,	604.	,,	,,
439.	,,	,,	494.	,,	13.	549.	,,	29.	605.	,,	29.
440.	,,	4.	495.	,,	12.	550.	,,	,,	606.	October	1.
441.	,,	5.	496.	,,	20.	551.	April	8.	607.	,,	7.
442.	,,	8.	497.	,,	19.	552.	,,	,,	608.	,,	11.
443.	,,	13.	498.	,,	20.	553.	,,	,,	609.	,,	15.
444.	,,	,,	499.	,,	,,	554.	,,	,,	610.	,,	19.
445.	,,	23.	500.	,,	28.	555.	,,	15.	611.	,,	22.
446.	,,	24.	501.	December	3.	556.	,,	,,	612.	,,	,,
447.	,,	25.	502.	,,	,,	557.	May	3.	613.	,,	,,
448.	,,	,,	503.	,,	,,	558.	,,	,,	614.	,,	28.
449.	,,	,,	504.	,,	10.	559.	,,	6.	615.	,,	31.
450.	June	1.	505.	,,	,,	560.	,,	7.	616.	,,	,,
451.	,,	,,	506.	,,	,,	561.	,,	12.	617.	November	14.
452.	,,	6.	507.	,,	,,	562.	,,	15.	618.	,,	,,
453.	,,	,,	508.	,,	12.	563.	,,	19.	619.	,,	18.
454.	,,	13.	509.	,,	14.	564.	,,	20.	620.	,,	,,
455.	,,	19.	510.	,,	18.	565.	,,	27.	621.	,,	22.
456.	,,	20.	511.	,,	22.	566.	,,	,,	622.	,,	25.
457.	,,	26.	512.	,,	,,	567.	,,	28.	623.	,,	,,
457*a*.	,,	23.	513.	,,	,,	568.	,,	30.	624.	,,	,,
458.	July	1.	514.	,,	23.	569.	,,	,,	625.	,,	29.
459.	,,	,,	515.	,,	24.	570.	,,	,,	626.	,,	,,
460.	,,	,,	516.	,,	30.	571.	June	4.	627.	December	5.
461.	,,	5.		1864.		572.		7.	628.	,,	9.
462.	,,	,,	517.	January	11.	573.	,,	10.	629.	,,	19.
463.	,,	6.	518.	,,	,,	574.	,,	13.	630.	,,	20.
464.	,,	9.	519.	,,	24.	575.	,,	15.	631.	,,	,,
465.	,,	14.	520.	,,	,,	576.	,,	30.			
466.	,,	18.	521.	,,	,,	577.	,,	,,			
467.	,,	26.	522.	,,	,,	578.	,,	,,			
468.	,,	29.	523.	,,	,,	579.	July	4.			
469.	August	3.	254.	,,	,,	580.	,,	6.			
470.	,,	5.	525.	,,	,,	581.	,,	9.			
471.	,,	10.	526.	,,	,,	582.	,,	,,			

17. In the following Table the monthly numbers of the groups of Table I. are compared with those independently obtained by Hofrath SCHWABE :—

	Number of groups observed at Kew.	Number of groups observed at Dessau.
1862.		
March . . .	8	14
April . . .	17	16
May	17	12
June . . .	31	14
July	29	13
August . . .	18	13
September . .	12	13
October . .	14	12
November . .	12	12
December . .	9	14
1863.		
January . . .	9	8
May	12	14
June	9	11
July	11	10
August . . .	8	10
September . .	6	10
October . . .	10	10
November . .	8	8
December . .	16	10
1864.		
January . . .	11	12
February . .	7	7
March . . .	16	17
April . . .	6	9
May	14	11
June	8	11
July	7	11
August . . .	12	12
September . .	8	9
October . . .	11	14
November . .	10	13
December . .	5	4

We thus see that, for 10 months of 1862, the number of new groups observed were

at Kew . . . 167 at Dessau . . . 133

in 9 months of 1863 they were

at Kew . . . 89 at Dessau . . . 91

while in 12 months of 1864 they were

at Kew . . . 115 at Dessau . . . 130

There is thus a slight difference in the system of grouping; but it may be hoped that if the observers in both places continue their labours for the next few years, there will then be little difficulty in attaching the one series to the other, so as not to break the continuity.

§ V. *Two Classes of Investigations.*

18. Our investigations may be divided into two classes—

(1.) Those in which remarks are made regarding the behaviour and appearance of spots and faculæ, and generalizations deduced therefrom, which do not involve accurate measurements.

(2.) There are, however, certain results in order to obtain which it is necessary to make use of accurate measurements of the position of spots: such are those from which CARRINGTON has deduced the proper motion of spots on the sun's surface. Probably for this class of observations no better method can be adopted

than that so ably pursued by him; but since we have materials at our disposal embracing accurate photographic delineations, we are perhaps called upon to attempt corrections which he has not applied.

19. *Correction for Solar Atmosphere.*—The most important of these is the correction due to the refraction of the solar atmosphere, which CARRINGTON has indicated, but without applying it, in his large volume. There are evident proofs of the existence of such an atmosphere; for

(1.) In the Kew photographs the central portion of the disk uniformly indicates a greater luminosity than the borders, as if the rays at the borders had to pass through a large extent of atmosphere. It is worthy of remark that the temperature of this atmosphere must be lower than that of the photosphere; otherwise the absorption which it occasions would be counterbalanced by its radiation.

(2.) The beautiful discovery of KIRCHHOFF leads to the same conclusion, since, in order to account for the dark lines of the solar spectrum, it is necessary to suppose the existence of a solar atmosphere of a lower temperature than the source of light.

(3.) The red flames which are visible during a total eclipse, and which have been proved to belong to the sun (Art. 9), indicate the existence of a solar atmosphere extending in some instances as far as 72,000 miles above the photosphere. This is confirmed by the nature of the light which these flames emit. Mr. DE LA RUE has found that this light is very rich in actinic rays, so much so that he was able to photograph at least one protuberance which was not visible to the eye. Now it is precisely this description of light which characterizes the electric discharge in which gaseous matter appears in a highly heated state.

20. Let us now endeavour to show the nature of those corrections which are rendered necessary by solar refraction.

(1.) A solar atmosphere will make the sun's photosphere to appear larger than it really is; but the angular distance between two points, each near the centre of the visible disk, will not be appreciably altered. This will introduce a slight error into the calculated position of any point, since in such a calculation we make use of the sun's apparent angular diameter, which is greater than his true diameter.

(2.) Apart from this, an error will be introduced into the calculation of the solar latitude and longitude of a point, this error depending upon its position in the visible disk, and being greater for those points which are at a distance from the centre.

§ VI. *Questions to be answered in the present Paper.*

21. In the present paper we shall attempt to answer the following questions:—

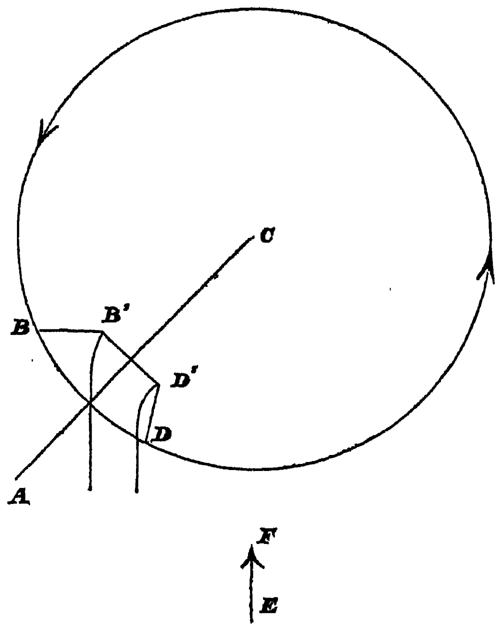
(I.) Is the umbra of a spot nearer the sun's centre than its penumbra? or, in other words, is it at a lower level?

(II.) Is the photosphere of our luminary to be viewed as composed of heavy

solid, or heavy liquid matter? or is it rather of the nature of a cloud? A short explanation will render evident the meaning of this question. There are two types, either of which we may conceive as representing the solar photosphere: we may, in the first place, suppose it to be a solid or liquid plane more or less uneven, with a heavy atmosphere above it. This atmosphere may be composed either of quite different materials from those of the liquid plane, or it may contain some of the materials of the plane in a state of vapour. Our own ocean is an example of this type, the air above it being composed chiefly of materials different from those of the ocean, but containing also aqueous vapour. On the other hand, we may imagine the sun's photosphere to resemble a cloud, the characteristic of which is solid or liquid particles of a greater or less size existing in a gaseous atmosphere, composed to a greater or less extent of the materials of the cloud. These points must be determined by observation alone. We must ask if the appearances presented by the sun's photosphere lead to the conclusion that it is an uneven plane of heavy liquid or solid matter, or do they induce us to imagine that it is rather of the nature of a cloud?

(III.) Is a spot, including both umbra and penumbra, a phenomenon which takes place beneath the level of the sun's photosphere or above it?

22. In the first place, therefore, and to answer the first question, let us see what will happen if the umbra of a spot be nearer the sun's centre than the penumbra?



If B′ D′, be the umbra of a spot, then (whether we regard the penumbra as a semi-opaque cloud, B D, or as sloping sides, B B′, D D′) to an observer viewing the phenomenon from the direction A C which passes through the centre of the umbra and penumbra, these two will appear symmetrically disposed with regard to each other, so that the umbra will seem to be precisely in the centre of the penumbra. But to an observer

viewing the phenomenon from the direction EF, it is obvious that the umbra will appear to be quite to the right of the penumbra.

Therefore if the umbra be lower than the penumbra, when a spot passes over the sun's disk, the umbra will always appear to encroach upon that side of the penumbra which is directed towards the visual centre of the sun's disk; and it is clear from the diagram which we have given, that this effect will be lessened through the refraction caused by a solar atmosphere, but we cannot conceive that it will be wholly obliterated. If therefore the umbra is appreciably at a lower level than the penumbra, we are entitled to look for an apparent encroachment of the former upon the latter on that side which is nearest the visual centre of the disk. This in fact was the phenomenon which WILSON observed, and which led him to the belief that the umbra was nearer the sun's centre than the penumbra.

23. In the following six sub-tables the effect of foreshortening is estimated in the direction from left to right, this being the direction in which spots advance across the visible disk by rotation; and for this purpose the whole surface of the sun has been divided into six portions, comprising 30° each.

TABLE II_a.

1. Spot left of central line, and within 30 degrees from left limb.

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to
		1858.				1859.	
1.	1.	March 11.	1·7	22.	116.	September 5.	1·2
2.	5.	„ 15.	2·0	23.	123.	„ 19.	3·0
3.	28.	August 28.	1·5	24.	131.	„ „	2·0
4.	27.	„ „	1·7	25.	125.	„ 20.	1·5
		1859.		26.	144.	October 2.	1·2
5.	44.	February 24.	1·0	27.	145.	November 11.	2·5
6.	44.	„ 25.	0·9			1861.	
7.	49.	March 1.	1·2	28.	160.	June 14.	2·5
8.	52.	„ 4.	2·0	29.	161.	„ „	2·0
9.	57.	„ 10.	0·9	30.	165.	„ „	2·0
10.	66.	„ 21.	3·0	31.	160.	„ 15.	2·5
11.	82.	April 11.	2·5	32.	169.	„ 17.	2·0
12.	97.	May 13.	2·0	33.	169.	„ 18.	2·0
13.	106.	August 25.	2·0	34.	173.	„ 23.	1·5
14.	107.	„ „	0·3	35.	173.	„ 24.	1·5
15.	116.	„ 28.	2·0	36.	186.	July 2.	2·0
16.	110.	„ 29.	2·2	37.	178.	„ „	1·5
17.	106.	„ 30.	1·3	38.	201.	November 16.	1·2
18.	116.	„ „	2·0	39.	207.	„ 28.	1·4
19.	106.	„ 31.	1·5	40.	208.	December 1.	3·0
20.	117.	September 1.	2·0	41.	210.	„ 3.	1·8
21.	116.	„ „	0·5	42.	213.	„ 5.	2·0

TABLE II$_a$. (*continued*).

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to
		1861.	
43.	217.	December 11.	1·5
		1862.	
44.	232.	February 7.	2·0
45.	233.	" "	1·5
46.	233.	" 8.	2·0
47.	234.	" 10.	2·0
48.	240.	" 20.	1·5
49.	240.	" 21.	2·0
50.	256.	March 31.	2·0
51.	259.	April 3.	1·2
52.	261.	" 14.	1·5
53.	265.	" 17.	2·0
54.	273.	May 1.	2·5
55.	275.	" 5.	2·0
56.	277.	" 9.	1·2
57.	279.	" 12.	2·5
58.	282.	" 16.	2·0
59.	285.	" 22.	2·0
60.	289.	" 29.	2·5
61.	304.	June 15.	0·9
62.	305.	" "	2·5
63.	305.	" 16.	2·0
64.	315.	" 23.	0·8
65.	316.	" "	1·2
66.	316.	" 24.	0·8
67.	317.	" "	0·3
68.	318.	" 25.	1·5
69.	322.	July 5.	1·5
70.	326.	" 8.	2·0
71.	331.	" 13.	1·1
72.	340.	" 25.	2·5
73.	346.	" 28.	2·5
74.	361.	August 19.	2·0
75.	361.	" 20.	2·0
76.	372.	September 15.	2·0
77.	372.	" 16.	1·5
78.	373.	" "	2·0
79.	374.	" "	2·0
80.	385.	October 8.	0·2
81.	387.	" 17.	1·8
82.	390.	" 23.	1·5
83.	390.	" 24.	1·2
84.	391.	" "	1·2
85.	406.	December 12.	3·0
86.	411.	" 25.	3·0
87.	414.	" 31.	1·4
		1863.	
88.	415.	January 7.	2·0
89.	418.	" 18.	1·5
90.	441.	May 6.	2·0
91.	445.	" 25.	1·2
92.	447.	" "	2·0
93.	447.	" 26.	1·5
94.	447.	" 27.	2·5
95.	451.	June 1.	2·0
96.	451.	" 2.	1·6
97.	456.	" 21.	1·5
98.	462.	July 6.	1·6
99.	463.	" "	2·5
100.	463.	" 7.	2·0
101.	465.	" 14.	1·3
102.	465.	" 15.	1·4
103.	467.	" 28.	2·5
104.	473.	August 11.	1·5
105.	480.	September 22.	1·7
106.	483.	October 5.	1·5
107.	485.	" 16.	2·0
108.	507.	December 10.	1·6
		1864.	
109.	540.	March 2.	1·6
110.	539.	" "	1·3
111.	543.	" 11.	2·0
112.	545.	" 17.	2·5
113.	544.	" "	1·5
114.	546.	" 18.	1·5
115.	550.	" 29.	2·0
116.	566.	May 27.	2·0
117.	575.	June 16.	2·0
118.	575.	" 17.	1·8
119.	578.	July 2.	1·3
120.	579.	" 5.	2·0
121.	579.	" 6.	1·5
122.	587.	August 1.	1·8
123.	591.	" 8.	1·1
124.	599.	September 3.	2·5
125.	602.	" 17.	3·0
126.	606.	October 1.	2·5
127.	611.	" 22.	1·6
128.	614.	" 28.	2·5
129.	616.	November 3.	1·7
130.	625.	" 29.	0·5

TABLE II_a. (*continued*).

2. Spot left of central line, and between 30 and 60 degrees from left limb.

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to
		1858.				1862.	
1.	20.	April 26.	2·0	46.	250.	March 7.	1·4
2.	28.	August 30.	1·2	47.	252.	,, 19.	2·0
		1859.		48.	256.	April 3.	1·4
3.	42.	February 19.	1·8	49.	259.	,, 4.	1·3
4.	49.	March 2.	1·0	50.	261.	,, 15.	1·0
5.	54.	,, 10.	1·3	51.	261.	,, 17.	1·2
6.	65.	,, 18.	0·9	52.	270.	,, 29.	1·5
7.	83.	April 11.	2·0	53.	270.	,, 30.	1·0
8.	77.	,, ,,	1·1	54.	273.	May 2.	2·0
9.	86.	,, ,,	1·2	55.	275.	,, 8.	1·3
10.	92.	,, 21.	0·8	56.	277.	,, 10.	1·1
11.	93.	,, ,,	1·0	57.	279.	,, 13.	2·0
12.	106.	August 28.	1·2	58.	282.	,, 19.	1·3
13.	107.	,, ,,	1·0	59.	287.	,, 26.	1·5
14.	107.	,, 29.	1·5	60.	288.	,, 29.	0·8
15.	106.	September 1.	1·5	61.	292.	June 2.	1·3
16.	119.	,, 3.	1·3	62.	292.	,, 3.	2·5
17.	131.	,, 20.	1·3	63.	293.	,, 4.	1·5
18.	124.	,, 21.	1·6	64.	304.	,, 16.	1·0
19.	136.	,, 29.	1·0	65.	304.	,, 17.	1·2
20.	139.	October 2.	1·3	66.	314.	,, 23.	1·6
21.	145.	,, 3.	1·3	67.	314.	,, 24.	1·8
22.	136.	,, ,,	1·5	68.	315.	,, ,,	0·7
23.	144.	,, 4.	1·2	69.	316.	,, 25.	1·3
24.	150.	November 11.	3·0	70.	336.	July 20.	2·0
25.	151.	,, ,,	2·0	71.	340.	,, 26.	1·2
		1861.		72.	346.	,, 31.	2·0
26.	160.	June 17.	2·0	73.	354.	August 6.	1·3
27.	165.	,, ,,	1·5	74.	357.	,, 15.	1·5
28.	168.	,, 18.	1·5	75.	361.	,, 21.	1·3
29.	169.	,, 19.	1·5	76.	361.	,, 22.	1·2
30.	169.	,, 20.	2·0	77.	372.	September 18.	1·3
31.	173.	,, 26.	1·4	78.	375.	,, 20.	0·1
32.	187.	July 2.	1·5	79.	401.	November 16.	1·2
33.	188.	,, ,,	1·2	80.	401.	,, 17.	1·2
34.	179.	,, ,,	0·7			1863.	
35.	194.	November 7.	1·8	81.	415.	January 8.	2·0
36.	201.	,, 18.	0·8	82.	441.	May 7.	1·2
37.	204.	,, 23.	1·5	83.	441.	,, 8.	1·3
38.	204.	,, ,,	1·5	84.	443.	,, 13.	1·1
39.	206.	December 1.	0·8	85.	445.	,, 26.	1·2
40.	210.	,, 4.	1·2	86.	445.	,, 27.	1·1
41.	217.	,, 15.	2·5	87.	448.	,, ,,	0·1
42.	222.	,, 20.	1·5	88.	447.	,, 28.	2·0
		1862.		89.	451.	June 4.	1·5
43.	232.	February 8.	1·2	90.	453.	,, 9.	1·5
44.	247.	,, 28.	2·0	91.	456.	,, 23.	1·2
45.	243.	,, ,,	1·2	92.	462.	July 7.	1·5

TABLE II$_a$. (*continued*).

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to
		1863.				1864.	
93.	462.	July 9.	1·0	106.	550.	March 31.	1·2
94.	465.	„ 17.	1·1	107.	556.	„ 19.	1·7
95.	467.	„ 29.	1·5	108.	572.	June 6.	1·1
96.	467.	„ 30.	1·5	109.	575.	„ 18.	1·4
97.	471.	August 10.	0·8	110.	578.	July 4.	1·1
98.	473.	„ 12.	1·3	111.	587.	August 2.	1·4
99.	481.	September 30.	1·2	112.	590.	„ 8.	1·1
100.	483.	October 6.	1·0	113.	599.	September 5.	1·1
101.	485.	„ 17.	1·5	114.	606.	October 3.	2·0
102.	507.	December 12.	2·0	115.	606.	„ 4.	1·2
		1864.		116.	615.	November 3.	1·5
103.	543.	March 12.	2·0	117.	616.	„ 4.	1·2
104.	544.	„ 18.	1·2	118.	623.	„ 25.	1·1
105.	544.	„ 19.	1·1	119.	625.	December 1.	0·7

3. Spot left of central line, and within 30 degrees from central line.

		1858.				1861.	
1.	1.	March 15.	2·0	30.	164.	June 14.	1·0
2.	21.	April 26.	3·0	31.	164.	„ 15.	1·1
3.	20.	„ 28.	1·0	32.	161.	„ 17.	1·2
4.	23.	August 24.	1·2	33.	160.	„ 18.	1·6
5.	23.	„ 26.	1·2	34.	161.	„ „	1·5
6.	23.	„ 31.	1·0	35.	172.	„ 23.	1·0
		1859.		36.	201.	November 19.	0·9
7.	48.	February 28.	0·2	37.	201.	„ 20.	1·0
8.	44.	„ „	0·9	38.	207.	December 1.	1·6
9.	48.	March 1.	0·4	39.	206.	„ 3.	1·2
10.	49.	„ 4.	1·0	40.	213.	„ 11.	1·2
11.	52.	„ 10.	1·0	41.	217.	„ 20.	1·0
12.	105 *a*.	May 13.	2·0			1862.	
13.	105 *b*.	„ „	0·3	42.	232.	February 10.	1·0
14.	105 *c*.	„ „	2·0	43.	243.	March 1.	1·5
15.	108.	August 25.	1·7	44.	256.	April 4.	1·2
16.	116.	„ 29.	1·1	45.	258.	„ „	1·3
17.	106.	„ 30.	1·0	46.	267.	„ 24.	1·8
18.	117.	„ 31.	1·0	47.	270.	May 1.	1·5
19.	120.	September 3.	1·5	48.	270.	„ 2.	1·3
20.	106.	„ 5.	1·2	49.	275.	„ 9.	1·0
21.	121.	„ 16.	1·2	50.	275.	„ 10.	1·0
22.	131.	„ 21.	1·0	51.	289.	June 1.	1·3
23.	124.	„ 22.	1·5	52.	292.	„ 4.	1·0
24.	124.	„ 24.	1·3	53.	304.	„ 18.	1·1
25.	135.	„ 29.	1·0	54.	316.	„ 26.	1·2
26.	145.	October 4.	1·2	55.	318.	„ 28.	2·0
27.	144.	„ 4.	1·1	56.	320.	July 1.	1·1
28.	136.	„ 5.	1·8	57.	325.	„ 11.	1·2
29.	149.	November 11.	1·0	58.	330.	„ 15.	1·1

TABLE II_{a}. (*continued*).

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *right* being equal to unity, that towards *left* is equal to
		1862.				1863.	
59.	331.	July 15.	1·1	74.	467.	July 31.	1·3
60.	353.	August 6.	0·8	75.	473.	August 15.	1·2
61.	353.	„ 7.	0·8	76.	512.	December 23.	1·2
62.	361.	„ 23.	1·1			1864.	
63.	361.	„ 24.	1·1	77.	539.	March 4.	0·9
64.	364.	„ 28.	1·2	78.	540.	„ „	1·2
65.	372.	September 19.	1·0	79.	550.	April 1.	1·1
66.	372.	„ 20.	1·0	80.	550.	„ 2.	1·0
		1863.		81.	553.	„ 9.	1·4
67.	422.	January 28.	1·0	82.	554.	„ 12.	2·5
68.	443.	May 14.	1·1	83.	575.	June 20.	1·2
69.	447.	„ 29.	2·5	84.	578.	July 7.	1·2
70.	450.	June 4.	2·0	85.	587.	August 6.	1·1
71.	453.	„ 10.	1·1	86.	597.	September 1.	1·0
72.	463.	July 9.	1·0	87.	606.	October 6.	0·9
73.	465.	„ 18.	1·0	88.	615.	November 4.	1·2

4. Spot right of central line, and within 30 degrees from central line.

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to
		1858.				1859.	
1.	2.	March 15.	1·2	19.	124.	September 19.	1·1
2.	12.	„ 27.	1·3	20.	131.	„ 22.	1·2
3.	21.	April 28.	1·0	21.	131.	„ 29.	1·5
4.	23.	August 28.	1·0	22.	136.	October 2.	1·5
5.	25.	„ 30.	1·2	23.	146.	„ 4.	1·1
6.	28.	„ 31.	1·0			1861.	
		1859.		24.	162.	June 17.	1·5
7.	35.	January 28.	1·2	25.	164.	„ „	0·7
8.	44.	March 1.	1·0	26.	162.	„ 18.	1·5
9.	62.	„ 18.	1·2	27.	160.	„ 19.	1·2
10.	65.	„ 21.	1·0	28.	160.	„ 20.	1·0
11.	74.	„ 11.	1·2	29.	169.	„ 23.	1·2
12.	111.	August 25.	1·0	30.	169.	„ 24.	1·5
13.	112.	„ „	1·3	31.	172.	„ „	1·1
14.	120.	September 1.	1·0	32.	180.	July 2.	1·5
15.	124.	„ 16.	0·8	33.	197.	November 15.	1·2
16.	125.	„ 17.	1·1	34.	197.	„ 16.	1·0
17.	125.	„ 18.	1·0	35.	207.	December 3.	0·8
18.	125.	„ 19.	1·1	36.	206.	„ 4.	1·2

TABLE II$_a$. (*continued*).

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to
		1861.				1862.	
37.	206.	December 5.	1·2	65.	411.	December 31.	0·9
38.	210.	„ 9.	1·1			1863.	
		1862.		66.	445.	June 1.	1·0
39.	243.	March 3.	0·8	67.	451.	„ 6.	1·0
40.	243.	„ 4.	0·8	68.	451.	„ 8.	0·9
41.	257.	April 4.	1·4	69.	453.	„ 13.	1·6
42.	261.	„ 20.	0·9	70.	456.	„ 27.	0·9
43.	267.	„ 25.	1·0	71.	462.	July 12.	1·2
44.	273.	May 5.	1·0	72.	464.	„ „	1·0
45.	278.	„ 17.	1·5	73.	467.	August 3.	1·0
46.	288.	June 1.	1·5	74.	469.	„ 10.	1·5
47.	289.	„ 3.	2·0	75.	471.	„ 17.	1·2
48.	289.	„ 4.	1·2	76.	487.	October 22.	1·4
49.	314.	„ 28.	0·8	77.	487.	„ 23.	1·4
50.	320.	July 5.	0·9	78.	505.	December 14.	1·3
51.	325.	„ 13.	0·9	79.	512.	„ 25.	1·0
52.	325.	„ 14.	1·8			1864.	
53.	335.	„ 18.	1·5	80.	517.	January 11.	1·0
54.	337.	„ 25.	1·5	81.	523.	„ 26.	1·1
55.	357.	August 21.	1·2	82.	527.	February 10.	1·0
56.	361.	„ 26.	0·9	83.	537.	March 4.	1·2
57.	364.	„ 29.	0·9	84.	543.	„ 16.	1·0
58.	364.	„ 30.	0·8	85.	543.	„ 17.	1·0
59.	369.	September 6.	2·0	86.	553.	April 11.	1·0
60.	378.	„ 30.	1·0	87.	553.	„ 12.	1·0
61.	378.	October 1.	1·0	88.	597.	September 3.	1·0
62.	387.	„ 21.	1·3	89.	606.	October 7.	1·0
63.	395.	November 12.	1·0	90.	611.	„ 28.	1·1
64.	411.	December 30.	1·0				

5. Spot right of central line, and between 30° and 60° from right limb.

		1858.				1859.	
1.	23.	August 30.	1·8	13.	116.	September 3.	1·3
		1859.		14.	120.	„ 5.	1·1
2.	36.	January 28.	0·8	15.	124.	„ 17.	1·0
3.	42.	February 24.	0·9	16.	130.	„ 20.	1·3
4.	48.	March 2.	1·1	17.	139.	October 2.	1·4
5.	44.	„ „	1·3	18.	145.	„ 3.	1·8
6.	60.	„ 18.	1·2	19.	139.	„ „	0·9
7.	64.	„ 21.	1·2	20.	142.	„ 4.	1·5
8.	62.	„ „	0·6	21.	152.	November 11.	1·3
9.	101.	May 13.	2·0	22.	154.	„ „	1·8
10.	102.	„ „	1·5			1861.	
11.	111.	August 28.	1·3	23.	164.	June 18.	1·0
12.	110.	„ „	2·0	24.	168.	„ 23.	1·7

TABLE II_a. (*continued*).

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to
		1861.				1862.	
25.	201.	November 23.	2·0	53.	361.	August 28.	0·9
26.	204.	„ 28.	0·7	54.	378.	October 3.	0·8
27.	207.	December 5.	0·8	55.	395.	November 13.	1·3
28.	210.	„ 11.	1·2	56.	401.	„ 23.	1·2
		1862.				1863.	
29.	240.	February 28.	1·5	57.	411.	January 2.	0·9
30.	244.	March 4.	1·3	58.	418.	„ 25.	1·1
31.	244.	„ 5.	2·0	59.	445.	June 2.	1·0
32.	245.	„ „	2·0	60.	451.	„ 9.	1·0
33.	243.	„ „	0·9	61.	456.	„ 29.	1·0
34.	252.	„ 24.	1·2	62.	462.	July 14.	1·0
35.	261.	April 21.	1·0	63.	464.	„ „	1·1
36.	267.	„ 26.	2·0	64.	467.	August 4.	1·5
37.	267.	„ 27.	2·0	65.	467.	„ 5.	2·0
38.	275.	May 13.	1·2	66.	471.	„ 19.	1·2
39.	278.	„ 19.	1·1	67.	481.	October 6.	1·5
40.	288.	June 2.	1·3	68.	503.	December 4.	1·1
41.	292.	„ 8.	1·2	69.	505.	„ 16.	1·1
42.	293.	„ 9.	0·6			1864.	
43.	293.	„ 10.	0·9	70.	519.	January 24.	1·1
44.	310.	„ 23.	1·6	71.	523.	„ 28.	0·9
45.	311.	„ „	2·0	72.	542.	March 16.	1·1
46.	320.	July 6.	1·3	73.	543.	„ 18.	1·2
47.	327.	„ 14.	2·5	74.	543.	„ 19.	1·5
48.	325.	„ 15.	1·5	75.	566.	June 4.	1·1
49.	325.	„ 16.	1·0	76.	572.	„ 11.	0·9
50.	340.	„ 31.	0·9	77.	585.	July 27.	2·5
51.	359.	August 20.	2·0	78.	623.	December 1.	1·1
52.	357.	„ 22.	2·0				

6. Spot right of central line, and within 30° from right limb.

		1859.				1859.	
1.	42.	February 25.	0·9	14.	140.	October 4.	2·0
2.	61.	March 21.	0·8	15.	139.	„ „	1·5
3.	103.	May 13.	1·5	16.	155.	November 11.	2·5
4.	114.	August 25.	1·0			1861.	
5.	112.	„ 28.	3·0	17.	160.	June 23.	1·5
6.	124.	September 18.	2·0	18.	160.	„ 24.	1·2
7.	130.	„ 19.	0·7	19.	171.	„ „	2·0
8.	130.	„ 21.	2·0	20.	173.	July 2.	0·5
9.	123.	„ 21.	1·5	21.	197.	November 19.	2·0
10.	130.	„ 22.	2·0	22.	196.	„ 20.	0·5
11.	123.	„ „	1·8	23.	204.	December 1.	1·8
12.	131.	„ 24.	1·5	24.	206.	„ 9.	0·5
13.	130.	„ 29.	1·5	25.	213.	„ 15.	3·0

TABLE II_a. (*continued*).

Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to	Running No.	No. of group in the Kew Catalogue.	Date.	The amount of penumbra of each spot towards *left* being equal to unity, that towards *right* is equal to
		1862.				1863.	
26.	229.	February 10.	2·0	64.	411.	January 4.	1·5
27.	232.	" 16.	1·3	65.	413.	" "	1·2
28.	234.	" 20.	1·1	66.	445.	June 4.	1·2
29.	239.	" "	1·8	67.	451.	" 10.	1·2
30.	240.	March 1.	1·2	68.	451.	" 11.	1·3
31.	261.	April 23.	2·0	69.	452.	" "	2·0
32.	261.	" 24.	2·0	70.	456.	" 30.	1·5
33.	267.	" 29.	1·8	71.	456.	July 1.	1·7
34.	267.	" 30.	2·0	72.	461.	" 6.	1·3
35.	273.	May 9.	1·2	73.	462.	" 15.	1·3
36.	287.	June 2.	1·5	74.	464.	" "	1·5
37.	288.	" 3.	0·9	75.	465.	" 24.	1·1
38.	288.	" 4.	2·0	76.	483.	October 13.	1·5
39.	289.	" 7.	1·0	77.	489.	November 1.	0·8
40.	289.	" 8.	1·3	78.	495.	" 22.	0·8
41.	289.	" 9.	1·4	79.	501.	December 4.	2·0
42.	293.	" 11.	0·9	80.	502.	" "	3·5
43.	316.	July 1.	1·1			1864.	
44.	315.	" "	3·0	81.	519.	January 26.	2·0
45.	320.	" 8.	0·9	82.	523.	" 30.	1·5
46.	322.	" 14.	2·0	83.	528.	February 10.	2·0
47.	322.	" 15.	1·5	84.	535.	March 2.	1·2
48.	327.	" 16.	3·0	85.	540.	" 10.	2·0
49.	325.	" 17.	2·0	86.	540.	" 11.	1·0
50.	334.	" 18.	1·5	87.	541.	" 17.	2·0
51.	340.	August 2.	1·1	88.	541.	" 18.	2·0
52.	359.	" 21.	2·0	89.	548.	April 1.	1·5
53.	357.	" 23.	2·0	90.	553.	" 14.	1·6
54.	361.	" 29.	0·6	91.	566.	June 6.	1·5
55.	361.	" 30.	0·8	92.	572.	" 14.	1·0
56.	364.	September 2.	1·5	93.	572.	" 15.	1·5
57.	364.	" 3.	1·6	94.	573.	" 18.	1·2
58.	364.	" 4.	1·8	95.	582.	July 21.	1·5
59.	372.	" 25.	1·5	96.	611.	October 31.	2·5
60.	373.	" "	2·0				
61.	377.	" 30.	2·5				
62.	378.	October 5.	0·7				
63.	401.	November 24.	1·2				

Result of TABLE II$_a$. Showing the effect of foreshortening in the direction left and right of the central line.

a. Giving the *mean ratios* between the two sides of the penumbra.

Left of central line.						*Right* of central line.					
Within 30° from left limb.		Between 30° and 60° from left limb.		Within 30° from central line.		Within 30° from central line.		Between 30° and 60° from right limb.		Within 30° from right limb.	
No. of spots observed.	The penumbra on the *right* side of a spot being equal to unity, that on the *left* is equal to	No. of spots observed.	The penumbra on the *right* side of a spot being equal to unity, that on the *left* is equal to	No. of spots observed.	The penumbra on the *right* side of a spot being equal to unity, that on the *left* is equal to	No. of spots observed.	The penumbra on the *left* side of a spot being equal to unity, that on the *right* is equal to	No. of spots observed.	The penumbra on the *left* side of a spot being equal to unity, that on the *right* is equal to	No. of spots observed.	The penumbra on the *left* side of a spot being equal to unity, that on the *right* is equal to
130	1·8	119	1·4	88	1·2	91	1·2	77	1·3	100	1·6

b. Giving the *percentage* of cases, out of 530 observations in all, which are in conformity with the assumption that the umbra is nearer to the centre of the sun than the penumbra, and of cases which are against it.

Left of central line.												*Right* of central line.											
Within 30° from left limb.				Between 30° and 60° from left limb.				Within 30° from central line.				Within 30° from central line.				Between 30° and 60° from right limb.				Within 30° from right limb.			
For.		Against.		For.		Against.		For.		Against.		For.		Against.		For.		Against.		For.		Against.	
No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
119	92·3	10	7·7	99	90·0	11	10·0	55	86·1	9	13·9	46	74·2	16	25·8	55	79·7	14	20·3	82	85·4	14	14·6

The whole number of cases observed is 605; excluding herefrom 75, where the penumbra is equal on both sides, there remain 530, of which 456, or 86·04 per cent. are *for*, and 74, or 13·96 per cent. are *against* the assumption.

TABLE II_b.

Showing the relative proportion of the penumbral part on opposite sides of Sun-spots, as this is affected by foreshortening in the direction above and below the Solar Equator.

Spot above the equator.

Running No.	No. of spot in Kew Catalogue.	Date of Sun-picture.		The lower part of the penumbra of each spot being equal to unity, the upper part is equal to
		1859.		
1.	34.	January	28.	1·4
2.	36.	„	„	1·2
3.	44.	February	25.	0·9
4.	48.	„	28.	0·6
5.	44.	„	„	1·2
6.	62.	March	18.	0·8
7.	60.	„	„	2·0
8.	62.	„	21.	1·2
9.	82.	April	11.	3·0
10.	97.	May	15.	2·0
11.	108.	August	25.	2·0
12.	107.	„	28.	1·5
13.	111.	„	„	1·2
14.	112.	„	„	3·0
15.	125.	September	16.	1·2
16.	150.	November	11.	1·6
		1861.		
17.	187.	July	2.	2·0
18.	188.	„	„	1·2
19.	206.	December	3.	1·5
20.	207.	„	„	0·9
21.	217.	„	20.	1·2
		1862.		
22.	243.	March	1.	2·0
23.	256.	April	3.	1·2
24.	292.	June	1.	1·4
25.	287.	„	2.	2·0
26.	292.	„	„	1·5
27.	293.	„	3.	2·0
28.	292.	„	7.	0·9
29.	357.	August	19.	1·5
30.	357.	„	20.	2·0
31.	357.	„	21.	2·0
32.	361.	„	26.	0·9
33.	391.	October	26.	1·2
34.	411.	December	30.	1·1
		1863.		
35.	440.	May	8.	2·0
36.	444.	„	13.	2·0
37.	443.	„	„	1·5
38.	445.	„	26.	1·2
39.	453.	June	9.	1·2
40.	456.	„	21.	1·3
41.	463.	July	14.	1·5
42.	471.	August	18.	2·0
		1864.		
43.	550.	March	31.	1·2
44.	554.	April	13.	2·0
45.	554.	„	14.	2·0
46.	554.	„	15.	1·5
47.	566.	May	30.	1·4
48.	587.	August	2.	2·0

Spot below the equator.

Running No.	No. of spot in Kew Catalogue.	Date of Sun-picture.		The upper part of the penumbra of each spot being equal to unity, the lower part is equal to
		1858.		
1.	1.	March	15.	1·5
2.	2.	„	„	1·2
3.	21.	April	23.	1·6
4.	23.	August	23.	1·2
5.	23.	„	28.	1·2
		1859.		
6.	42.	February	23.	1·3
7.	45.	„	25.	0·7
8.	42.	„	„	0·8
9.	63.	March	18.	2·0
10.	64.	„	„	0·9
11.	61.	„	„	0·8
12.	75.	April	7.	2·0
13.	93.	„	21.	1·3
14.	92.	„	„	1·1
15.	105^{a}.	May	13.	3·0
16.	105^{b}.	„	„	0·3
17.	103.	„	„	2·0
18.	110.	August	25.	2·2
19.	116.	„	30.	1·2
20.	142.	September	29.	2·0
21.	142.	October	2.	2·0
22.	136.	„	„	1·5
23.	145.	„	4.	1·5
24.	157.	November	11.	2·0
25.	158.	„	„	1·5
		1861.		
26.	169.	June	23.	1·3
27.	173.	„	26.	1·4
		1862.		
28.	267.	April	26.	0·6
29.	289.	June	1.	1·2
30.	289.	„	2.	1·3
31.	289.	„	7.	1·3
32.	340.	July	26.	1·4
33.	346.	August	1.	0·8
34.	346.	„	2.	0·8
35.	346.	„	5.	0·7
36.	359.	„	18.	1·5
37.	390.	October	26.	0·9
		1863.		
38.	473.	August	18.	1·4
		1864.		
39.	561.	May	16.	1·2
40.	572.	June	10.	1·3
41.	590.	August	8.	0·6

Result of TABLE II_b.

Showing the effect of foreshortening in the direction above and below the Equator.

Above the equator.					Below the equator.				
The lower part of the penumbra of each spot being equal to unity, the upper part is equal to	For assumption.		Against assumption.		The upper part of the penumbra of each spot being equal to unity, the lower part is equal to	For assumption.		Against assumption.	
	No. of cases.	Per cent.	No. of cases.	Per cent.		No. of cases.	Per cent.	No. of cases.	Per cent.
1·54	42	87·5	6	12·5	1·33	30	73·2	11	26·8

The whole number of cases considered is 89, of which 72, or 80·9 per cent., are for, and 17, or 19·1 per cent., against the assumption, that the umbra is nearer to the centre of the sun than the penumbra.

In Table II_b, since the relative disposition of umbra and penumbra is estimated in directions parallel to circles of solar longitude, only spots having a high solar latitude have been considered.

It will be seen that the results of Tables II_a. and II_b. are decidedly in favour of WILSON'S hypothesis.

24. Let us now endeavour to answer the second question—"Is the photosphere of our luminary to be viewed as composed of heavy liquid or solid matter, or is it of the nature of a cloud?" One characteristic of the sun's surface is the appearance (especially in connexion with spots) of faculæ, or patches of a brightness greater than that of the photosphere immediately around them, this difference in brightness being much more conspicuous near the limb than near the centre. One explanation of these phenomena would be, that the luminous matter of the sun has been thrown up to a great elevation in order to form faculæ. This would account for the greater comparative luminosity of faculæ near the border. For we have already mentioned (Art. 19) that the absorbing effect of the solar atmosphere is very perceptible near the border, where the light reaching us has to travel through a great thickness of atmosphere; and hence, if the luminous matter be thrown up to a great elevation, it will, near the border, escape a great portion of this atmosphere, and will therefore appear relatively much brighter than the surface around it. On the other hand, very little will be gained when the matter is thrown up near the visual centre, where we may imagine the atmospheric absorption to be comparatively small. The idea that faculæ are portions of the photosphere raised above the general surface, appears to be confirmed by stereoscopic pictures of spots obtained by Mr. DE LA RUE, where the faculæ appear as elevated ridges surrounding the spots. Accepting this conclusion, we next remark that faculæ often retain the same appearance for several days together, as if their matter were capable of remaining suspended for some time.

Now if we suppose that such faculæ represent the ordinary luminous matter of the sun,

the facts above recorded would appear to throw much light upon the nature of the solar surface, since we cannot easily imagine faculæ to be only the most elevated positions of a liquid ocean, which has heen pushed high up into the solar atmosphere, or to be portions of matter projected from such an ocean. Such an hypothesis would appear to be inconsistent with the fact that faculæ retain their appearance unchanged for days together. At any rate we venture to think that such an hypothesis would not readily be received, and that, according to the rules which ought to guide our judgment in a case like the present, it ought to be set aside if we can find a more plausible explanation. Such an explanation would appear to consist in supposing that faculæ, and, indeed, the whole photosphere of our luminary, are more of the nature of a cloud. A cloud has been defined by Sir J. HERSCHEL to consist of solid or liquid matter, formed from the condensation of a vapour not *floating* in æquilibrio, but sinking in a gaseous medium of less specific gravity than itself—sinking, however, with extreme slowness, owing to the minuteness of its particles, and consequent (relatively) enormous resistance of the air. This illustrious savant is disposed to think that the consideration of CAGNIARD DE LATOUR'S experiments on the vaporization of liquids under high pressure would incline us to regard the solar faculæ as large aggregations of *bonâ fide solid matter* of a high degree of fixity, and in masses like gigantic soot-flakes of any form and magnitude, which, when formed, settle down to such a level as corresponds to their density when they rest *in æquilibrio* in a gaseous fluid of their own specific gravity. We do not wish either to accept or to reject this hypothesis, but would frame the following statement, which also includes this view of the case: *Solar faculæ consist of solid or liquid bodies of a greater or less magnitude, either slowly sinking or suspended in æquilibrio in a gaseous medium.*

25. In connexion with this part of our subject it will be well to investigate the relative position of spots and their accompanying faculæ; and this is done in the following Table for all the Kew pictures available for this purpose.

Table III.

Showing the relative position of Sun-spots and the accompanying Faculæ.

Running No.	Group *left* of central line.						Group *right* of central line.					
	Position of Facula.											
	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.
	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.
1.	44	..	3	21	1	20	126	..	2	16	12	7
2.	44	..	4	105	1	14	125	..	9	41	12	14–15
3.	48	..	5	119	6	15	124	..	10	45	15	46
4.	135	..	13	134	14	78	172	..	8	45	20	61
5.	175	..	13	213	15	96	267	..	17	60	21	67
6.	201	..	21	248	20	116–117	358	..	19	71	26	74
7.	220	..	20	248	23	116–117	438	..	13	111	25	162
8.	256	..	22	264	23	116–117	..	..	14	131	35	174
9.	268	..	24	269	24	124	..	..	29	136	37	196–197
10.	289	..	25	285	27	129	..	..	29	204	38	196–197
11.	325	..	26	337	30	131	..	..	23	277	43	196–197
12.	385	..	25	348	31	131	..	..	32	324	42	309–310
13.	445	..	27	361	39	131	..	..	33	344	47	501
14.	475	..	28	360	41	132	..	..	36	344	42	536
15.	528	..	28	372	44	148	..	..	41	370	41	..
16.	589	..	28	414	52	149	..	..	46	396	45	..
17.	625	..	34	449	53	162	..	..	46	437	48	..
18.	..	..	40	560	63	162	..	..	47	437	44	..
19.	..	..	42	587	79	169–170	..	..	41	527	44	..
20.	..	..	45	..	86	173	..	..	47	541	59	..
21.	..	..	49	..	77	173	..	..	42	541	57	..
22.	..	..	48	..	90	173	..	..	48	548	58	..
23.	..	..	50	..	93	182–183	..	..	49	548	64	..
24.	..	..	49	..	104	189–190	..	..	65	552	70	..
25.	..	..	51	..	106	191	..	..	62	567	66	..
26.	..	..	49	..	109	232–233	..	..	68	571	76	..
27.	..	..	57	..	106	274	..	..	69	..	98	..
28.	..	..	58	..	107	304–305	..	..	70	..	103	..
29.	..	..	56	..	106	315–316	..	..	68	..	112	..
30.	..	..	64	..	119	311	..	..	69	..	111	..
31.	..	..	65	..	121	325–329	..	..	75	..	110	..
32.	..	..	66	..	117	340–342	..	..	76	..	106	..
33.	..	..	68	..	122	347–350	..	..	68	..	127	..
34.	..	..	69	..	130	353–354	..	..	69	..	124	..
35.	..	..	73	..	139	361–363	..	..	100	..	124	..
36.	..	..	74	..	145	445–447	..	..	100	..	136	..
37.	..	..	74	..	152	445–447	..	..	101	..	140	..
38.	..	..	77	..	165	445–447	..	..	102	..	142	..
39.	..	..	82	..	164	462–463	..	..	110	..	157	..
40.	..	..	83	..	162	474 *a*	..	..	114	..	162	..
41.	..	..	85	..	165	544–545	..	..	112	..	164	..
42.	..	..	88	..	171	561	..	..	110	..	165	..
43.	..	..	89	..	172	569–570	..	..	108	..	165	..
44.	..	..	91	..	191	611–612	..	..	111	..	164	..
45.	..	..	92	..	192	615–616	..	..	108	..	165	..
46.	..	..	97	..	196	..	..	..	107	..	172	..

TABLE III. (*continued*).

Running No.	Group *left* of central line.						Group *right* of central line.					
	Position of Facula.											
	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.
	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.
47.	..	..	107	..	202	..	..	..	126	..	180	..
48.	..	..	108	..	206	..	..	..	127	..	177	..
49.	..	..	107	..	209	..	..	..	125	..	210	..
50.	..	..	117	..	206	..	..	..	126	..	213	..
51.	..	..	123	..	207	..	..	..	125	..	216	..
52.	..	..	122	..	209	..	..	..	125	..	228	..
53.	..	..	129	..	211	..	..	..	127	..	229	..
54.	..	..	130	..	212	..	..	..	123	..	230	..
55.	..	..	130	..	216	..	..	..	129	..	239	..
56.	..	..	133	..	218	..	..	..	123	..	239	..
57.	..	..	130	..	217	..	..	..	129	..	245	..
58.	..	..	132	..	219	..	..	..	130	..	245	..
59.	..	..	133	..	224	..	..	..	135	..	254	..
60.	..	..	134	..	230	..	..	..	138	..	263	..
61.	..	..	123	..	243–247	..	..	..	135	..	261	..
62.	..	..	124	..	248	..	..	..	139	..	261	..
63.	..	..	129	..	255	..	..	..	142	..	261	..
64.	..	..	136	..	256	..	..	..	140	..	269	..
65.	..	..	135	..	261	..	..	..	143	..	273	..
66.	..	..	141	..	261	..	..	..	147	..	274	..
67.	..	..	142	..	261	..	..	..	139	..	273	..
68.	..	..	143	..	264	..	..	..	136	..	274	..
69.	..	..	145	..	265	..	..	..	139	..	275	..
70.	..	..	144	..	266	..	..	..	140	..	277	..
71.	..	..	145	..	267	..	..	..	144	..	277	..
72.	..	..	144	..	266	..	..	..	158	..	278	..
73.	..	..	144	..	267	..	..	..	167	..	286	..
74.	..	..	145	..	267	..	..	..	164	..	290	..
75.	..	..	151	..	269	..	..	..	164	..	294	..
76.	..	..	150	..	269	..	..	..	160	..	292	..
77.	..	..	160	..	270	..	..	..	161	..	294	..
78.	..	..	161	..	269	..	..	..	169	..	293	..
79.	..	..	160	..	270	..	..	..	160	..	293	..
80.	..	..	161	..	275	..	..	..	168	..	297	..
81.	..	..	165	..	275	..	..	..	171	..	303	..
82.	..	..	160	..	276	..	..	..	169	..	309	..
83.	..	..	168	..	277	..	..	..	160	..	314	..
84.	..	..	169	..	275	..	..	..	168	..	315	..
85.	..	..	170	..	279	..	..	..	171	..	316	..
86.	..	..	165	..	285	..	..	..	169	..	318	..
87.	..	..	169	..	288	..	..	..	171	..	320	..
88.	..	..	170	..	287	..	..	..	181	..	321	..
89.	..	..	160	..	289	..	..	..	173	..	323	..
90.	..	..	161	..	292	..	..	..	195	..	322	..
91.	..	..	168	..	289	..	..	..	195	..	327	..
92.	..	..	169	..	292	..	..	..	195	..	325	..
93.	..	..	172	..	303	..	..	..	197	..	325	..
94.	..	..	176	..	301	..	..	..	198	..	326	..
95.	..	..	178	..	301	..	..	..	198	..	326	..

TABLE III. (*continued*).

Running No.	Group *left* of central line. Position of Facula. Wholly left. No. of group.	Group *left* of central line. Position of Facula. Wholly right. No. of group.	Group *left* of central line. Position of Facula. Mostly left. No. of group.	Group *left* of central line. Position of Facula. Mostly right. No. of group.	Group *left* of central line. Position of Facula. Equally all round. No. of group.	Group *left* of central line. Position of Facula. Between spots. No. of group.	Group *right* of central line. Position of Facula. Wholly left. No. of group.	Group *right* of central line. Position of Facula. Wholly right. No. of group.	Group *right* of central line. Position of Facula. Mostly left. No. of group.	Group *right* of central line. Position of Facula. Mostly right. No. of group.	Group *right* of central line. Position of Facula. Equally all round. No. of group.	Group *right* of central line. Position of Facula. Between spots. No. of group.
96.	..	..	179	..	303	..	..	..	203	..	325	..
97.	..	..	186	..	305	..	..	..	207	..	327	..
98.	..	..	187	..	301	..	..	..	208	..	336	..
99.	..	..	188	..	303	..	..	..	206	..	337	..
100.	..	..	190	..	301	..	..	..	211	..	340	..
101.	..	..	192	..	303	..	..	..	210	..	342	..
102.	..	..	196	..	306	..	..	..	211	..	343	..
103.	..	..	200	..	305	..	..	..	226	..	343	..
104.	..	..	201	..	315	..	..	..	227	..	345	..
105.	..	..	200	..	318	..	..	..	226	..	345	..
106.	..	..	201	..	322	..	..	..	228	..	343	..
107.	..	..	202	..	322	..	..	..	232	..	357	..
108.	..	..	204	..	322	..	..	..	234	..	364	..
109.	..	..	204	..	330	..	..	..	234	..	367	..
110.	..	..	205	..	331	..	..	..	242	..	367	..
111.	..	..	208	..	331	..	..	..	240	..	370	..
112.	..	..	210	..	336	..	..	..	242	..	372	..
113.	..	..	211	..	337	..	..	..	240	..	381	..
114.	..	..	210	..	334	..	..	..	243	..	402	..
115.	..	..	209	..	337	..	..	..	244	..	407	..
116.	..	..	210	..	339	..	..	..	244	..	413	..
117.	..	..	211	..	340	..	..	..	243	..	441	..
118.	..	..	213	..	336	..	..	..	243	..	444	..
119.	..	..	214	..	343	..	..	..	261	..	446	..
120.	..	..	217	..	343	..	..	..	261	..	445	..
121.	..	..	213	..	348	..	..	..	266	..	451	..
122.	..	..	221	..	351	..	..	..	267	..	452	..
123.	..	..	222	..	348	..	..	..	267	..	457	..
124.	..	..	223	..	351	..	..	..	272	..	456	..
125.	..	..	225	..	353–354	..	..	..	272	..	457	..
126.	..	..	229	..	345	..	..	..	274	..	456	..
127.	..	..	233	..	353	..	..	..	275	..	457	..
128.	..	..	234	..	354	..	..	..	278	..	461	..
129.	..	..	233	..	358	..	..	..	287	..	459	..
130.	..	..	240	..	360	..	..	..	288	..	459	..
131.	..	..	240	..	360	..	..	..	290	..	462	..
132.	..	..	242	..	362	..	..	..	289	..	470	..
133.	..	..	243	..	363	..	..	..	289	..	471	..
134.	..	..	247	..	362	..	..	..	292	..	482	..
135.	..	..	249	..	368	..	..	..	292	..	481	..
136.	..	..	248	..	369	..	..	..	293	..	484	..
137.	..	..	249	..	367	..	..	..	297	..	493	..
138.	..	..	250	..	370	..	..	..	295	..	495	..
139.	..	..	252	..	373	..	..	..	298	..	493	..
140.	..	..	259	..	374	..	..	..	298	..	495	..
141.	..	..	259	..	375	..	..	..	302	..	511	..
142.	..	..	265	..	380	..	..	..	311	..	510	..
143.	..	..	265	..	388	..	..	..	311	..	514	..
144.	..	..	267	..	391	..	..	..	305	..	513	..

TABLE III. (*continued*).

Running No.	Group *left* of central line.						Group *right* of central line.					
	Position of Facula.											
	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.
	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.
145.	..	..	273	..	391	..	..	..	322	..	519	..
146.	..	..	273	..	402	..	..	..	327	..	523	..
147.	..	..	277	..	410	..	..	..	322	..	529	..
148.	..	..	277	..	414	..	..	..	327	..	540	..
149.	..	..	276	..	443	..	..	..	325	..	542	..
150.	..	..	279	..	444	..	..	..	330	..	542	..
151.	..	..	282	..	448	..	..	..	332	..	541	..
152.	..	..	282	..	448	..	..	..	346	..	543	..
153.	..	..	282	..	450	..	..	..	346	..	547	..
154.	..	..	286	..	450	..	..	..	346	..	547	..
155.	..	..	286	..	451	..	..	..	359	..	548	..
156.	..	..	292	..	456	..	..	..	357	..	548	..
157.	..	..	293	..	456	..	..	..	359	..	552	..
158.	..	..	293	..	456	..	..	..	358	..	560	..
159.	..	..	296	..	468	..	..	..	361	..	561	..
160.	..	..	301	..	468	..	..	..	366	..	561	..
161.	..	..	304	..	468	..	..	..	361	..	564	..
162.	..	..	304	..	471	..	..	..	361	..	566	..
163.	..	..	308	..	481	..	..	..	364	..	566	..
164.	..	..	317	..	492	..	..	..	364	..	568	..
165.	..	..	314	..	492	..	..	..	369	..	571	..
166.	..	..	312	..	493	..	..	..	369	..	573	..
167.	..	..	317	..	498–499	..	..	..	369	..	573	..
168.	..	..	316	..	507	..	..	..	370	..	573	..
169.	..	..	317	..	525	..	..	..	373	..	576	..
170.	..	..	318	..	541	..	..	..	376	..	576	..
171.	..	..	319	..	541	..	..	..	377	..	579	..
172.	..	..	319	..	544	..	..	..	378	..	581	..
173.	..	..	320	..	545	..	..	..	396	..	579	..
174.	..	..	320	..	544	..	..	..	401	..	581	..
175.	..	..	326	..	545	..	..	..	408	..	579	..
176.	..	..	327	..	548	..	..	..	409	..	579	..
177.	..	..	331	..	561	..	..	..	411	..	582	..
178.	..	..	336	..	562	..	..	..	411	..	583	..
179.	..	..	342	..	572	..	..	..	414	..	582	..
180.	..	..	345	..	572	..	..	..	418	..	583	..
181.	..	..	345	..	575	..	..	..	422	..	582	..
182.	..	..	346	..	575	..	..	..	422	..	583	..
183.	..	..	346	..	573	..	..	..	439	..	582	..
184.	..	..	345	..	574	..	..	..	446	..	584	..
185.	..	..	346	..	575	..	..	..	445	..	585	..
186.	..	..	347	..	575	..	..	..	445	..	584	..
187.	..	..	345	..	575	..	..	..	450	..	585	..
188.	..	..	346	..	576	..	..	..	450	..	586	..
189.	..	..	357	..	578	..	..	..	451	..	587	..
190.	..	..	358	..	579	..	..	..	450	..	587	..
191.	..	..	361	..	581	..	..	..	451	..	592	..
192.	..	..	363	..	582	..	..	..	458	..	592	..
193.	..	..	361	..	582	..	..	..	456	..	592	..

TABLE III. (*continued*).

Running No.	Group *left* of central line.						Group *right* of central line.					
	Position of Facula.											
	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.
	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.
194.	..	..	361	..	582	..	..	..	461	..	589	..
195.	..	..	363	..	582	..	..	..	463	..	591	..
196.	..	..	364	..	584	..	..	..	462	..	589	..
197.	..	..	360	..	586	..	..	..	463	..	591	..
198.	..	..	364	..	587	..	..	..	465	..	590	..
199.	..	..	365	..	586	..	..	..	468	..	597	..
200.	..	..	364	..	590	..	..	..	473	..	601	..
201.	..	..	367	..	589	..	..	..	475	..	603	..
202.	..	..	370	..	591	..	..	..	483	..	603	..
203.	..	..	372	..	590	..	..	..	483	..	605	..
204.	..	..	375	..	597	..	..	..	484	..	605	..
205.	..	..	375	..	599	..	..	..	489	..	605	..
206.	..	..	387	..	599	..	..	..	489	..	605	..
207.	..	..	390	..	601	..	..	..	489	..	606	..
208.	..	..	393	..	604	..	..	..	491	..	605	..
209.	..	..	399	..	605	..	..	..	505	..	606	..
210.	..	..	399	..	605	..	..	..	512	..	608	..
211.	..	..	400	..	605	..	..	..	520	..	609	..
212.	..	..	403	..	606	..	..	..	521	..	614	..
213.	..	..	406	..	605	..	..	..	528	..	614	..
214.	..	..	411	..	606	..	..	..	535	..	617	..
215.	..	..	413	..	606	..	..	..	537	..	618	..
216.	..	..	415	..	606	..	..	..	540	..	621	..
217.	..	..	418	..	606	..	..	..	540	..	622	..
218.	..	..	418	..	606	..	..	..	542	..	622	..
219.	..	..	420	..	610	..	..	..	551	..	623	..
220.	..	..	423	..	613	..	..	..	553	..	624	..
221.	..	..	441	..	610	..	..	..	554	..	..	..
222.	..	..	446	..	612	..	..	..	556	..	..	..
223.	..	..	446	..	614	..	..	..	557	..	..	..
224.	..	..	448	..	616	..	..	..	557	..	..	..
225.	..	..	451	..	616	..	..	..	558	..	..	..
226.	..	..	451	..	618	..	..	..	560	..	..	..
227.	..	..	451	..	623	..	..	..	569	..	..	..
228.	..	..	453	..	622	..	..	..	566	..	..	..
229.	..	..	453	..	626	..	..	..	571	..	..	..
230.	..	..	465	..	..	..	..	..	568	..	..	..
231.	..	..	465	..	..	..	..	..	572	..	..	..
232.	..	..	467	..	..	..	..	..	572	..	..	..
233.	..	..	467	..	..	..	..	..	572	..	..	..
234.	..	..	469	..	..	..	..	..	576	..	..	..
235.	..	..	469	..	..	..	..	..	581	..	..	..
236.	..	..	469	..	..	..	..	..	581	..	..	..
237.	..	..	472	..	..	..	..	..	579	..	..	..
238.	..	..	473	..	..	..	..	..	581	..	..	..
239.	..	..	472	..	..	..	..	..	586	..	..	..
240.	..	..	472	..	..	..	..	..	586	..	..	..
241.	..	..	473	..	..	..	..	..	590	..	..	..
242.	..	..	477*a*	..	..	..	..	..	591	..	..	..

TABLE III. (*continued*).

Running No.	Group *left* of central line.						Group *right* of central line.					
	Position of Facula.											
	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.	Wholly left.	Wholly right.	Mostly left.	Mostly right.	Equally all round.	Between spots.
	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.	No. of group.
243.	..	..	477*a*	..	..	..	..	..	606	..	..	..
244.	..	..	480	..	..	..	..	..	606	..	..	..
245.	..	..	480	..	..	..	..	..	609	..	..	..
246.	..	..	481	..	..	..	..	..	610	..	..	..
247.	..	..	483	..	..	..	..	..	611	..	..	..
248.	..	..	483	..	..	..	..	..	616	..	..	..
249.	..	..	485	..	..	..	..	..	..	..	..	..
250.	..	..	485	..	..	..	..	..	..	..	..	..
251.	..	..	493	..	..	..	..	..	..	..	..	..
252.	..	..	495	..	..	..	..	..	..	..	..	..
253.	..	..	510	..	..	..	..	..	..	..	..	..
254.	..	..	513	..	..	..	..	..	..	..	..	..
255.	..	..	511	..	..	..	..	..	..	..	..	..
256.	..	..	513	..	..	..	..	..	..	..	..	..
257.	..	..	511	..	..	..	..	..	..	..	..	..
258.	..	..	515	..	..	..	..	..	..	..	..	..
259.	..	..	525	..	..	..	..	..	..	..	..	..
260.	..	..	529	..	..	..	..	..	..	..	..	..
261.	..	..	540	..	..	..	..	..	..	..	..	..
262.	..	..	539	..	..	..	..	..	..	..	..	..
263.	..	..	543	..	..	..	..	..	..	..	..	..
264.	..	..	543	..	..	..	..	..	..	..	..	..
265.	..	..	543	..	..	..	..	..	..	..	..	..
266.	..	..	544	..	..	..	..	..	..	..	..	..
267.	..	..	546	..	..	..	..	..	..	..	..	..
268.	..	..	546	..	..	..	..	..	..	..	..	..
269.	..	..	546	..	..	..	..	..	..	..	..	..
270.	..	..	550	..	..	..	..	..	..	..	..	..
271.	..	..	553	..	..	..	..	..	..	..	..	..
272.	..	..	554	..	..	..	..	..	..	..	..	..
273.	..	..	554	..	..	..	..	..	..	..	..	..
274.	..	..	556	..	..	..	..	..	..	..	..	..
275.	..	..	556*a*	..	..	..	..	..	..	..	..	..
276.	..	..	558	..	..	..	..	..	..	..	..	..
277.	..	..	559	..	..	..	..	..	..	..	..	..
278.	..	..	559	..	..	..	..	..	..	..	..	..
279.	..	..	563	..	..	..	..	..	..	..	..	..
280.	..	..	563	..	..	..	..	..	..	..	..	..
281.	..	..	566	..	..	..	..	..	..	..	..	..
282.	..	..	566	..	..	..	..	..	..	..	..	..
283.	..	..	566	..	..	..	..	..	..	..	..	..
284.	..	..	571	..	..	..	..	..	..	..	..	..
285.	..	..	577	..	..	..	..	..	..	..	..	..
286.	..	..	578	..	..	..	..	..	..	..	..	..
287.	..	..	577	..	..	..	..	..	..	..	..	..
288.	..	..	579	..	..	..	..	..	..	..	..	..
289.	..	..	578	..	..	..	..	..	..	..	..	..
290.	..	..	579	..	..	..	..	..	..	..	..	..
291.	..	..	584	..	..	..	..	..	..	..	..	..

TABLE III. (*continued*).

Running No.	Group *left* of central line. Position of Facula. Wholly left. No. of group.	Wholly right. No. of group.	Mostly left. No. of group.	Mostly right. No. of group.	Equally all round. No. of group.	Between spots. No. of group.	Group *right* of central line. Position of Facula. Wholly left. No. of group.	Wholly right. No. of group.	Mostly left. No. of group.	Mostly right. No. of group.	Equally all round. No. of group.	Between spots. No. of group.
292.	.	..	584	..	..	..	..	..	..	..	..	..
293.	..	..	590	..	..	..	..	..	..	..	..	..
294.	..	..	589	..	..	..	..	..	..	..	..	..
295.	..	..	590	..	..	..	..	..	..	..	..	..
296.	..	..	589	..	..	..	..	..	..	..	..	..
297.	..	..	591	..	..	..	..	..	..	..	..	..
298.	..	..	595	..	..	..	..	..	..	..	..	..
299.	..	..	597	..	..	..	..	..	..	..	..	..
300.	..	..	598*a*	..	..	..	..	..	..	..	..	..
301.	..	..	602	..	..	..	..	..	..	..	..	..
302.	..	..	604	..	..	..	..	..	..	..	..	..
303.	..	..	608	..	..	..	..	..	..	..	..	..
304.	..	..	613	..	..	..	..	..	..	..	..	..
305.	..	..	611	..	..	..	..	..	..	..	..	..
306.	..	..	614	..	..	..	..	..	..	..	..	..
307.	..	..	615	..	..	..	..	..	..	..	..	..
308.	..	..	615	..	..	..	..	..	..	..	..	..
309.	..	..	620	..	..	..	..	..	..	..	..	..
310.	..	..	624	..	..	..	..	..	..	..	..	..
311.	..	..	626	..	..	..	..	..	..	..	..	..
312.	..	..	625	..	..	..	..	..	..	..	..	..

Result of TABLE III.

Facula entirely or mostly *left* of spot.		Facula entirely or mostly *right* of spot.		Facula *all round* or between the spots.	
No. of cases.	Per cent. of the whole.	No. of cases.	Per cent. of the whole.	No. of cases.	Per cent. of the whole.
584	51·4	45	4·0	508	44·6

26. It appears from the result of Table III. that out of 1137 cases 584 have their faculæ either entirely or mostly on the left, while 508 have it nearly equally on both sides, and only 45 mostly on the right. Hence we see that faculæ are on an average to the left of their accompanying spots. The most obvious explanation of this would be that the faculæ of a spot have been uplifted from the very area occupied by that spot, and have fallen behind to the left from being thrown up into a region of greater velocity of rotation. All this is quite in accordance with our hypothesis regarding the nature of faculæ. We would likewise here remind our readers that we know from the observations of KIRCHHOFF that the sun's atmosphere contains vapours of substances, such as

iron, which are condensed into the liquid or solid state at a comparatively high temperature. Now is it not natural to suppose that in the sun's photosphere we do really see such vapours so condensed, and very unnatural to imagine that such vapours are seldom or never condensed, and that what we really see is an incandescent plain underlying these vapours.

27. Let us now attempt to answer the third question: Is a spot including both umbra and penumbra a phenomenon which takes place beneath the level of the sun's photosphere or above it? To decide this question, let us state that there are a good many instances in which a spot breaks up in the following manner. A bridge of luminous matter of the same apparent luminosity as the surrounding photosphere, and unaccompanied by any penumbra, appears to cross over the umbra or centre of a spot. There is good reason to think that this bridge is really above the spot; for were the umbra an opaque cloud, and the penumbra a semiopaque cloud, both being above the sun's photosphere, it is unlikely that the spot would break up in such a manner that the terrestrial observer should not perceive some penumbra accompanying the luminosity. Again, detached portions of luminous matter appear to move across a spot without producing any permanent alteration. We are on these accounts disposed to think that a spot including both umbra and penumbra is a phenomenon which takes place beneath the level of the brighter part of the sun's photosphere.

28. Let us here recapitulate the answers we have given to our three questions.

(1.) The umbra of a spot is nearer the sun's centre than its penumbra, or, in other words, it is at a lower level.

(2.) Solar faculæ, and probably also the whole photosphere, consist of solid or liquid bodies of greater or less magnitude, either slowly sinking or suspended *in æquilibrio* in a gaseous medium.

(3.) A spot including both umbra and penumbra is a phenomenon which takes place beneath the level of the sun's photosphere.

§ VII. *Concluding Remarks.*

29. It would thus appear that the central part of a spot is nearer the sun's centre than the penumbra, and that both the umbra and the penumbra are probably beneath the general level of the surrounding photosphere. Now the umbra or lowest part of a spot is much less luminous than the general photosphere. But what does this probably imply, according to the laws with which we are acquainted? It implies that in a spot there is probably some matter of a lower temperature than the photosphere. For is it not now recognized as a law, that if a substance, or combination of substances, of indefinite thickness and surface of small reflecting power have all its particles at a certain fixed temperature, this substance will give out nearly all the rays of heat belonging to that temperature? Now the sun, even when we look into a spot, is certainly a substance of

indefinite thickness; and since a spot appears much less luminous than the ordinary surface, ought we not to conclude either that we there view matter of a lower temperature than the ordinary surface, or that the matter which appears within a spot has a very high reflecting power compared to the ordinary matter of the photosphere? This last supposition is an unlikely one, and the probability is that in a spot we view matter of a lower temperature than the photosphere.

30. Presuming this to be the case, it appears to imply one of three things.

(1.) Either the general body of the sun at the level of the bottom of a spot is of a lower temperature than the photosphere;

(2.) Or the lower temperature is produced by some chemical or molecular process which takes place when a spot is formed;

(3.) Or it is produced by matter coming from a colder region.

The first of these suppositions will not be generally received unless we are fairly driven to accept it.

The second hypothesis has already been started to account for the lower temperature of a spot; but we think that, according to the laws by which we should be guided in receiving or rejecting an explanation in a case of this nature, this idea ought to be rejected.

No doubt, if we knew of a case of the production of low temperature, and had at the same time an independent proof of some chemical or molecular process, such as evaporation, it would be quite allowable for us to associate the chemical or molecular process with the production of cold as at any rate the most likely hypothesis; but we do not advance in our explanation of the low temperature by attributing it to an imaginary process of the existence of which we have no proof, and which is equally mysterious with the phenomenon for which it is supposed to account. Rather let us see if this reduction of temperature can be explained by any other phenomenon of the existence of which we have independent evidence. This leads us to consider the third hypothesis, which supposes that the reduction is produced by matter coming from a colder region. Now, in the first place, we have such a region in the atmosphere above the photosphere, which (Art. 19) we have shown to be of a lower temperature than the photosphere itself. Again, the observations of CHACORNAC and LOCKYER on the behaviour of the matter surrounding a spot appear to suggest the existence of a downward current, which is therefore a current from the colder regions above *. On the other hand, the proper motion of spots observed by CARRINGTON is in favour of this hypothesis, since a current coming from a region of greater to a region of less absolute velocity of rotation would be carried on forward, and most so nearest the equator; and this is precisely the motion of spots observed by CARRINGTON. Again, we have seen (Art. 26) that the faculæ fall behind; so that we may imagine two currents to be engaged in the formation of a spot,—the one

* Does not the observation by LOCKYER of the facula "giving out" appear also to indicate that the lower regions of a spot are in reality hotter than the surface, leaving the inferior luminosity to be accounted for by the downrush of a cold atmosphere from above?

an ascending current carrying the hot matter behind, the other a descending current carrying the cold matter forward. One advantage of this explanation is that all the gradations of darkness, from the faculæ to the central umbra, are thus supposed to be due to the same cause—namely, the presence to a greater or less extent of a comparatively cold absorbing atmosphere.

31. It is but just to ourselves and to M. FAYE, to mention that both have imagined the phenomenon of sun-spots to be due to ascending and descending currents. M. FAYE's hypothesis was published a little before ours; but we shall readily be believed when we state that an idea of this kind presided over the construction of Table III., in which we have proved that the faculæ are, on an average, to the left of their accompanying spots. It was not, however, until a short time before the publication of the abstract of this paper by the Royal Society, that, by discussing the subject together, we had matured our views so far as to connect the descending current, not only with CARRINGTON's proper motion, but also with the presumed lower temperature of a spot. In this last respect our hypothesis differs entirely from that of M. FAYE, who does not imagine that the inferior luminosity of a spot indicates the presence of matter at a lower temperature than the photosphere.

32. In conclusion, we would venture to suggest that if the photosphere of the sun be the plane of condensation of gaseous matter, this plane may be found to be subject to periodical elevations and depressions in the solar atmosphere. It may be that at the epoch of minimum spot-frequency this plane is uplifted very high in the solar atmosphere, so that there is comparatively little cold absorbing atmosphere above it, and therefore great difficulty in forming a spot. If this were the case we might expect a *less* atmospheric effect or gradation of luminosity from the centre to the circumference at the epoch of minimum than at that of maximum spot-frequency. Perhaps on some future occasion we may be able to produce evidence of this, and even of the unequal atmospheric effect of the two limbs of the sun at the same time; but in the meantime we shall content ourselves with suggesting this to the observers of our luminary as a simple inquiry that may possibly prove productive.

33. We are especially desirous of bringing under the early notice of the scientific world the accumulation of observations we are making, in order that others may put forth their own conjectures in elucidation of solar physics. In venturing the opinions we have stated, we do so with some reserve, and with the conviction that possibly they may hereafter require modifications.

November 13th, 1865.

AUXILIARY TABLES

FOR DETERMINING

THE ANGLE OF POSITION OF THE SUN'S AXIS

AND THE

LATITUDE AND LONGITUDE OF THE EARTH

REFERRED TO

THE SUN'S EQUATOR.

BY

WARREN DE LA RUE, D.C.L., F.R.S., V.P.R.A.S., &c.

PRINTED FOR PRIVATE CIRCULATION.

LONDON:

TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET, E.C.

1875.

THESE Tables, which have been computed by Mr. MARTH, are employed in the reduction of the ten-year series of solar photograms taken at Kew. As they are of general application in the reduction of observations of the Sun, I have thought that they would be acceptable to Astronomers, and have had some copies printed for private circulation.

Assumed inclination of the sun's equator to the ecliptic, 7° 15′·00.

Assumed longitude of the ascending node$=74°-\nu$.

The argument of the column "Angle between the circle of declination and the sun's axis" is the sun's longitude, ⊙. The Angle is considered positive when the sun's axis is to the West of the North point of the sun's disk. An additional correction is required to allow for the difference between the true and the assumed obliquity of the ecliptic, 23° 27′·50. This correction may be found by the Table given on page 20.

The argument of the columns "Heliographical latitude of the Earth" and "Reduction of longitude" is $\odot+\nu$.

Heliographical longitude of the Earth$=180°+\odot+$Reduction of longitude.

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
0° 0′	+25° 28′·00	1·21	+·122ν	−6° 58′·06	0·35	+ 7′·34
10	29·21	1·21		57·71	·35	7·40
20	30·42	1·19		57·36	·36	7·47
30	31·61	1·18	·122	57·00	·37	7·54
40	32·79	1·17		56·63	·36	7·61
50	33·96	1·15		56·27	·37	7·67
1 0	+25 35·11	1·15	+·121	−6 55·90	·38	+ 7·74
10	36·26	1·13		55·52	·37	7·81
20	37·39	1·13		55·15	·38	7·87
30	38·52	1·11	·121	54·77	·39	7·94
40	39·63	1·09		54·38	·39	8·01
50	40·72	1·09		53·99	·39	8·07
2 0	+25 41·81	1·08	+·120	−6 53·60	·39	+ 8·14
10	42·89	1·06		53·21	·40	8·21
20	43·95	1·05		52·81	·40	8·27
30	45·00	1·04	·120	52·41	·40	8·33
40	46·04	1·03		52·01	·41	8·39
50	47·07	1·01		51·60	·42	8·46
3 0	+25 48·08	1·00	+·120	−6 51·18	·41	+ 8·52
10	49·08	1·00		50·77	·42	8·58
20	50·08	0·98		50·35	·42	8·65
30	51·06	·96	·119	49·93	·43	8·71
40	52·02	·96		49·50	·43	8·77
50	52·98	·94		49·07	·43	8·83
4 0	+25 53·92	·94	+·119	−6 48·64	·44	+ 8·90
10	54·86	·92		48·20	·44	8·96
20	55·78	·91		47·76	·44	9·02
30	56·69	·89	·119	47·32	·45	9·08
40	57·58	·89		46·87	·45	9·14
50	58·47	·87		46·42	·45	9·20
5 0	+25 59·34	·86	+·119	−6 45·97	·46	+ 9·26
10	26 0·20	·85		45·51	·46	9·32
20	1·05	·83		45·05	·46	9·38
30	1·88	·83	·118	44·59	·47	9·44
40	2·71	·81		44·12	·47	9·50
50	3·52	·80		43·65	·48	9·55
6 0	+26 4·32	·79	+·118	−6 43·17	·48	+ 9·61
10	5·11	·78		42·69	·48	9·67
20	5·89	·76		42·21	·48	9·73
30	6·65	·75	·118	41·73	·49	9·78
40	7·40	·74		41·24	·49	9·84
50	8·14	·73		40·75	·49	9·90
7 0	+26 8·87	·72	+·117	−6 40·26	·50	+ 9·95
10	9·59	·70		39·76	·50	10·01
20	10·29	·69		39·26	·51	10·06
30	10·98	·68	·117	38·75	·51	10·12
40	11·66	·67		38·24	·51	10·17
50	12·33	·66		37·73	·51	10·23
8 0	+26 12·99	·64	+·116	−6 37·22	·52	+10·28
10	13·63	·63		36·70	·52	10·34
20	14·26	·62		36·18	·53	10·39
30	14·88	·61	·116	35·65	·53	10·44
40	15·49	·59		35·12	·53	10·49
50	16·08	·58		34·59	·53	10·55
9 0	+26 16·66	·57	+·115	−6 34·06	·54	+10·60
10	17·23	·56		33·52	·54	10·65
20	17·79	·55		32·98	·55	10·70
30	18·34	·53	·114	32·43	·55	10·75
40	18·87	·52		31·88	·55	10·80
50	19·39	0·51		31·33	0·56	10·85
10 0	+26 19·90		+·114ν	−6 30·77		+10·90

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
10° 0′	+26° 19′·90	0·50	+·114ν	−6° 30′·77	0·56	+10′·90
10	20·40	·48		30·21	·56	10·95
20	20·88	·47		29·65	·56	11·00
30	21·35	·46	·113	29·09	·57	11·05
40	21·81	·45		28·52	·57	11·09
50	22·26	·43		27·95	·58	11·14
11 0	+26 22·69	·43	+·113	−6 27·37	·58	+11·19
10	23·12	·41		26·79	·58	11·24
20	23·53	·40		26·21	·58	11·28
30	23·93	·38	·112	25·63	·59	11·33
40	24·31	·37		25·04	·59	11·37
50	24·68	·36		24·45	·59	11·42
12 0	+26 25·04	·35	+·112	−6 23·86	·60	+11·46
10	25·39	·34		23·26	·60	11·51
20	25·73	·32		22·66	·61	11·55
30	26·05	·32	·111	22·05	·61	11·60
40	26·37	·30		21·44	·61	11·64
50	26·67	·28		20·83	·61	11·68
13 0	+26 26·95	·27	+·111	−6 20·22	·62	+11·73
10	27·22	·27		19·60	·62	11·77
20	27·49	·25		18·98	·62	11·81
30	27·74	·23	·110	18·36	·63	11·85
40	27·97	·23		17·73	·63	11·89
50	28·20	·21		17·10	·63	11·93
14 0	+26 28·41	·20	+·110	−6 16·47	·64	+11·97
10	28·61	·19		15·83	·64	12·01
20	28·80	·17		15·19	·64	12·05
30	28·97	·16	·109	14·55	·65	12·09
40	29·13	·15		13·90	·65	12·13
50	29·28	·14		13·25	·65	12·17
15 0	+26 29·42	·12	+·109	−6 12·60	·65	+12·21
10	29·54	·11		11·95	·66	12·24
20	29·65	·10		11·29	·66	12·28
30	29·75	·09	·108	10·63	·67	12·32
40	29·84	·07		9·96	·67	12·35
50	29·91	·06		9·29	·67	12·39
16 0	+26 29·97	·05	+·107	−6 8·62	·67	+12·42
10	30·02	·04		7·95	·68	12·46
20	30·06	·02		7·27	·68	12·49
30	30·08	·01	·107	6·59	·68	12·53
40	30·09	·00		5·91	·69	12·56
50	30·09	·01		5·22	·69	12·59
17 0	+26 30·08	·03	+·106	−6 4·53	·69	+12·63
10	30·05	·04		3·84	·70	12·66
20	30·01	·05		3·14	·70	12·69
30	29·96	·06	·106	2·44	·70	12·72
40	29·90	·08		1·74	·70	12·75
50	29·82	·09		1·04	·71	12·78
18 0	+26 29·73	·11	+·105	−6 0·33	·71	+12·81
10	29·62	·11		5 59·62	·72	12·84
20	29·51	·13		58·90	·71	12·87
30	29·38	·14	·104	58·19	·72	12·90
40	29·24	·15		57·47	·73	12·93
50	29·09	·17		56·74	·72	12·96
19 0	+26 28·92	·18	+·104	−5 56·02	·73	+12·98
10	28·74	·19		55·29	·74	13·01
20	28·55	·21		54·55	·73	13·04
30	28·34	·21	·103	53·82	·74	13·06
40	28·13	·23		53·08	·74	13·09
50	27·90	0·25		52·34	0·74	13·11
20 0	+26 27·65		+·102ν	−5 51·60		+13·14

☉		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
°	′	° ′			° ′		′
20	0	+26 27.65	0.25	+.102ν	−5 51.60	0.75	+13.14
	10	27.40	.27		50.85	.75	13.16
	20	27.13	.28		50.10	.75	13.19
	30	26.85	.29	.102	49.35	.76	13.21
	40	26.56	.31		48.59	.76	13.23
	50	26.25	.32		47.83	.76	13.26
21	0	+26 25.93	.33	+.101	−5 47.07	.76	+13.28
	10	25.60	.35		46.31	.77	13.30
	20	25.25	.36		45.54	.77	13.32
	30	24.89	.37	.100	44.77	.78	13.34
	40	24.52	.38		43.99	.77	13.36
	50	24.14	.40		43.22	.78	13.38
22	0	+26 23.74	.41	+.100	−5 42.44	.79	+13.40
	10	23.33	.42		41.65	.78	13.42
	20	22.91	.43		40.87	.79	13.44
	30	22.48	.45	.099	40.08	.79	13.46
	40	22.03	.46		39.29	.79	13.47
	50	21.57	.47		38.50	.80	13.49
23	0	+26 21.10	.49	+.098	−5 37.70	.80	+13.51
	10	20.61	.50		36.90	.80	13.52
	20	20.11	.51		36.10	.81	13.54
	30	19.60	.53	.098	35.29	.81	13.55
	40	19.07	.53		34.48	.81	13.57
	50	18.54	.55		33.67	.81	13.58
24	0	+26 17.99	.57	+.097	−5 32.86	.81	+13.60
	10	17.42	.57		32.05	.82	13.61
	20	16.85	.59		31.23	.83	13.62
	30	16.26	.61	.096	30.40	.82	13.64
	40	15.65	.61		29.58	.83	13.65
	50	15.04	.63		28.75	.83	13.66
25	0	+26 14.41	.64	+.095	−5 27.92	.83	+13.67
	10	13.77	.65		27.09	.84	13.68
	20	13.12	.67		26.25	.84	13.69
	30	12.45	.68	.095	25.41	.84	13.70
	40	11.77	.70		24.57	.84	13.71
	50	11.07	.70		23.73	.85	13.72
26	0	+26 10.37	.72	+.094	−5 22.88	.85	+13.73
	10	9.65	.73		22.03	.85	13.74
	20	8.92	.75		21.18	.86	13.74
	30	8.17	.76	.093	20.32	.85	13.75
	40	7.41	.77		19.47	.86	13.76
	50	6.64	.78		18.61	.87	13.76
27	0	+26 5.86	.80	+.092	−5 17.74	.86	+13.77
	10	5.06	.81		16.88	.87	13.77
	20	4.25	.82		16.01	.87	13.78
	30	3.43	.84	.092	15.14	.87	13.78
	40	2.59	.85		14.27	.88	13.79
	50	1.74	.86		13.39	.88	13.79
28	0	+26 0.88	.87	+.091	−5 12.51	.88	+13.79
	10	26 0.01	.89		11.63	.89	13.79
	20	25 59.12	.90		10.74	.88	13.80
	30	25 58.22	.92	.090	9.86	.89	13.80
	40	25 57.30	.92		8.97	.89	13.80
	50	25 56.38	.94		8.08	.90	13.80
29	0	+25 55.44	.96	+.089	−5 7.18	.90	+13.80
	10	54.48	.96		6.28	.90	13.80
	20	53.52	.98		5.38	.90	13.80
	30	52.54	0.99	.088	4.48	.90	13.79
	40	51.55	1.01		3.58	.91	13.79
	50	50.54	1.02		2.67	0.91	13.79
30	0	+25 49.52		+.088ν	−5 1.76		+13.79

☉		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
°	′	° ′			° ′		′
30	0	+25 49.52	1.03	+.088ν	−5 1.76	0.91	+13.79
	10	48.49	1.04		5 0.85	.92	13.78
	20	47.45	1.06		4 59.93	.92	13.78
	30	46.39	1.07	.087	4 59.01	.92	13.78
	40	45.32	1.08		4 58.09	.92	13.77
	50	44.24	1.10		4 57.17	.93	13.77
31	0	+25 43.14	1.11	+.086	−4 56.24	.92	+13.76
	10	42.03	1.12		55.32	.93	13.75
	20	40.91	1.14		54.39	.94	13.75
	30	39.77	1.15	.085	53.45	.93	13.74
	40	38.62	1.16		52.52	.94	13.73
	50	37.46	1.18		51.58	.94	13.72
32	0	+25 36.28	1.18	+.084	−4 50.64	.94	+13.72
	10	35.10	1.20		49.70	.95	13.71
	20	33.90	1.22		48.75	.94	13.70
	30	32.68	1.23	.084	47.81	.95	13.69
	40	31.45	1.24		46.86	.95	13.68
	50	30.21	1.25		45.91	.96	13.67
33	0	+25 28.96	1.27	+.083	−4 44.95	.96	+13.66
	10	27.69	1.28		43.99	.96	13.64
	20	26.41	1.29		43.03	.96	13.63
	30	25.12	1.30	.082	42.07	.96	13.62
	40	23.82	1.32		41.11	.97	13.61
	50	22.50	1.34		40.14	.97	13.59
34	0	+25 21.16	1.34	+.081	−4 39.17	.97	+13.58
	10	19.82	1.36		38.20	.97	13.56
	20	18.46	1.37		37.23	.98	13.55
	30	17.09	1.38	.080	36.25	.97	13.53
	40	15.71	1.40		35.28	.98	13.52
	50	14.31	1.41		34.30	.99	13.50
35	0	+25 12.90	1.42	+.079	−4 33.31	.98	+13.49
	10	11.48	1.44		32.33	.99	13.47
	20	10.04	1.45		31.34	.99	13.45
	30	8.59	1.46	.078	30.35	.99	13.43
	40	7.13	1.48		29.36	0.99	13.41
	50	5.65	1.49		28.37	1.00	13.39
36	0	+25 4.16	1.50	+.078	−4 27.37	1.00	+13.37
	10	25 2.66	1.51		26.37	1.00	13.35
	20	25 1.15	1.53		25.37	1.00	13.33
	30	24 59.62	1.55	.077	24.37	1.01	13.31
	40	24 58.07	1.55		23.36	1.01	13.29
	50	24 56.52	1.57		22.35	1.01	13.27
37	0	+24 54.95	1.58	+.076	−4 21.34	1.01	+13.25
	10	53.37	1.59		20.33	1.01	13.23
	20	51.78	1.61		19.32	1.02	13.20
	30	50.17	1.62	.075	18.30	1.02	13.18
	40	48.55	1.63		17.28	1.02	13.16
	50	46.92	1.64		16.26	1.02	13.13
38	0	+24 45.28	1.66	+.074	−4 15.24	1.03	+13.11
	10	43.62	1.67		14.21	1.02	13.08
	20	41.95	1.69		13.19	1.03	13.06
	30	40.26	1.69	.073	12.16	1.03	13.03
	40	38.57	1.71		11.13	1.04	13.00
	50	36.86	1.73		10.09	1.03	12.97
39	0	+24 35.13	1.74	+.072	−4 9.06	1.04	+12.95
	10	33.39	1.75		8.02	1.04	12.92
	20	31.64	1.76		6.98	1.04	12.89
	30	29.88	1.78	.071	5.94	1.04	12.86
	40	28.10	1.79		4.90	1.05	12.83
	50	26.31	1.80		3.85	1.05	12.80
40	0	+24 24.51		+.070ν	−4 2.80		+12.77

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
40° 0′	+24° 24′·51	1·81	+·070ν	−4° 2′·80	1·05	+12′·77
10	22·70	1·83		4 1·75	1·05	12·74
20	20·87	1·84		4 0·70	1·05	12·71
30	19·03	1·85	·069	3 59·65	1·06	12·68
40	17·18	1·87		3 58·59	1·06	12·65
50	15·31	1·88		3 57·53	1·06	12·62
41 0	+24 13·43	1·89	+·069	−3 56·47	1·06	+12·58
10	11·54	1·91		55·41	1·06	12·55
20	9·63	1·92		54·35	1·07	12·52
30	7·71	1·93	·068	53·28	1·07	12·48
40	5·78	1·94		52·21	1·07	12·45
50	3·84	1·96		51·14	1·07	12·41
42 0	+24 1·88	1·97	+·067	−3 50·07	1·07	+12·38
10	23 59·91	1·98		49·00	1·08	12·34
20	57·93	2·00		47·92	1·07	12·31
30	55·93	2·01	·066	46·85	1·08	12·27
40	53·92	2·02		45·77	1·08	12·23
50	51·90	2·03		44·69	1·09	12·20
43 0	+23 49·87	2·05	+·065	−3 43·60	1·08	+12·16
10	47·82	2·06		42·52	1·09	12·12
20	45·76	2·07		41·43	1·09	12·08
30	43·69	2·09	·064	40·34	1·09	12·04
40	41·60	2·10		39·25	1·09	12·00
50	39·50	2·11		38·16	1·10	11·96
44 0	+23 37·39	2·13	+·063	−3 37·06	1·09	+11·92
10	35·26	2·14		35·97	1·10	11·88
20	33·12	2·15		34·87	1·10	11·84
30	30·97	2·16	·062	33·77	1·10	11·80
40	28·81	2·17		32·67	1·10	11·76
50	26·64	2·19		31·57	1·11	11·72
45 0	+23 24·45	2·21	+·061	−3 30·46	1·11	+11·68
10	22·24	2·21		29·35	1·10	11·63
20	20·03	2·23		28·25	1·11	11·59
30	17·80	2·24	·060	27·14	1·12	11·55
40	15·56	2·25		26·02	1·11	11·50
50	13·31	2·26		24·91	1·12	11·46
46 0	+23 11·05	2·28	+·059	−3 23·79	1·11	+11·41
10	23 8·77	2·29		22·68	1·12	11·37
20	23 6·48	2·31		21·56	1·12	11·32
30	23 4·17	2·31	·058	20·44	1·12	11·28
40	23 1·86	2·33		19·32	1·13	11·23
50	22 59·53	2·34		18·19	1·12	11·18
47 0	+22 57·19	2·36	+·057	−3 17·07	1·13	+11·14
10	54·83	2·36		15·94	1·13	11·09
20	52·47	2·38		14·81	1·13	11·04
30	50·09	2·40	·056	13·68	1·13	10·99
40	47·69	2·40		12·55	1·14	10·94
50	45·29	2·42		11·41	1·13	10·89
48 0	+22 42·87	2·43	+·055	−3 10·28	1·14	+10·85
10	40·44	2·44		9·14	1·14	10·80
20	38·00	2·46		8·00	1·14	10·75
30	35·54	2·46	·054	6·86	1·14	10·70
40	33·08	2·48		5·72	1·14	10·64
50	30·60	2·50		4·58	1·14	10·59
49 0	+22 28·10	2·50	+·053	−3 3·44	1·15	+10·54
10	25·60	2·52		3 2·29	1·15	10·49
20	23·08	2·53		3 1·14	1·15	10·44
30	20·55	2·54	·052	2 59·99	1·15	10·39
40	18·01	2·56		2 58·84	1·15	10·33
50	15·45	2·56		2 57·69	1·15	10·28
50 0	+22 12·89		+·051ν	−2 56·54		+10·23

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
50° 0′	+22° 12′·89	2·58	+·051ν	−2° 56′·54	1·16	+10′·23
10	22 10·31	2·60		55·38	1·15	10·17
20	22 7·71	2·60		54·23	1·16	10·12
30	22 5·11	2·62	·050	53·07	1·16	10·06
40	22 2·49	2·63		51·91	1·16	10·01
50	21 59·86	2·64		50·75	1·17	9·95
51 0	+21 57·22	2·65	+·049	−2 49·58	1·16	+ 9·90
10	54·57	2·67		48·42	1·16	9·84
20	51·90	2·68		47·26	1·17	9·79
30	49·22	2·69	·048	46·09	1·17	9·73
40	46·53	2·70		44·92	1·17	9·67
50	43·83	2·72		43·75	1·17	9·61
52 0	+21 41·11	2·73	+·047	−2 42·58	1·17	+ 9·56
10	38·38	2·74		41·41	1·18	9·50
20	35·64	2·75		40·23	1·17	9·44
30	32·89	2·76	·046	39·06	1·17	9·38
40	30·13	2·78		37·89	1·18	9·32
50	27·35	2·79		36·71	1·18	9·26
53 0	+21 24·56	2·80	+·045	−2 35·53	1·18	+ 9·21
10	21·76	2·81		34·35	1·18	9·15
20	18·95	2·83		33·17	1·19	9·09
30	16·12	2·84	·044	31·98	1·18	9·03
40	13·28	2·85		30·80	1·19	8·96
50	10·43	2·86		29·61	1·18	8·90
54 0	+21 7·57	2·87	+·043	−2 28·43	1·19	+ 8·84
10	21 4·70	2·88		27·24	1·19	8·78
20	21 1·82	2·90		26·05	1·19	8·72
30	20 58·92	2·91	·042	24·86	1·19	8·66
40	20 56·01	2·92		23·67	1·19	8·59
50	20 53·09	2·94		22·48	1·20	8·53
55 0	+20 50·15	2·94	+·041	−2 21·28	1·19	+ 8·47
10	47·21	2·96		20·09	1·19	8·40
20	44·25	2·97		18·90	1·20	8·34
30	41·28	2·98	·040	17·70	1·20	8 28
40	38·30	2·99		16·50	1·20	8·21
50	35·31	3·00		15·30	1·20	8·15
56 0	+20 32·31	3·02	+·039	−2 14·10	1·20	+ 8·08
10	29·29	3·03		12·90	1·21	8·02
20	26·26	3·04		11·69	1·20	7·95
30	23·22	3·05	·038	10·49	1·20	7·89
40	20·17	3·06		9·29	1·21	7·82
50	17·11	3·07		8·08	1·21	7·76
57 0	+20 14·04	3·09	+·037	−2 6·87	1·21	+ 7·69
10	20 10·95	3·10		5·66	1·21	7·63
20	20 7·85	3·11		4·45	1·21	7·56
30	20 4·74	3·12	·036	3·24	1·21	7·49
40	20 1·62	3·13		2·03	1·21	7·42
50	19 58·49	3·15		2 0·82	1·21	7·35
58 0	+19 55·34	3·15	+·035	−1 59·61	1·22	+ 7·29
10	52·19	3·17		58·39	1·21	7·22
20	49·02	3·18		57·18	1·22	7·15
30	45·84	3·19	·033	55·96	1·22	7·08
40	42·65	3·20		54·74	1·21	7·01
50	39·45	3·21		53·53	1·22	6·94
59 0	+19 36·24	3·22	+·032	−1 52·31	1·22	+ 6·87
10	33·02	3·24		51·09	1·23	6·81
20	29·78	3·25		49·86	1·22	6·74
30	26·53	3·25	·031	48·64	1·22	6·67
40	23·28	3·27		47·42	1·22	6·60
50	20·01	3·28		46·20	1·23	6·53
60 0	+19 16·73		+·030ν	−1 44·97		+ 6·45

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
60°	0′	+19° 16′·73	3·30	+·030	−1° 44′·97	1·22	+6′·45
	10	19 13·43	3·30		43·75	1·23	6·38
	20	19 10·13	3·31		42·52	1·23	6·31
	30	19 6·82	3·33	·029	41·29	1·23	6·24
	40	19 3·49	3·33		40·06	1·22	6·17
	50	19 0·16	3·35		38·84	1·23	6·10
61	0	+18 56·81	3·36	+·028	−1 37·61	1·23	+6·03
	10	18 53·45	3·37		36·38	1·24	5·95
	20	18 50·08	3·38		35·14	1·23	5·88
	30	18 46·70	3·39	·027	33·91	1·23	5·81
	40	18 43·31	3·40		32·68	1·23	5·74
	50	18 39·91	3·41		31·45	1·24	5·66
62	0	+18 36·50	3·43	+·026	−1 30·21	1·24	+5·59
	10	18 33·07	3·43		28·97	1·24	5·52
	20	18 29·64	3·45		27·73	1·23	5·44
	30	18 26·19	3·45	·025	26·50	1·23	5·37
	40	18 22·74	3·47		25·27	1·24	5·30
	50	18 19·27	3·48		24·03	1·24	5·22
63	0	+18 15·79	3·49	+·024	−1 22·79	1·24	+5·15
	10	18 12·30	3·50		21·55	1·24	5·07
	20	18 8·80	3·51		20·31	1·24	5·00
	30	18 5·29	3·52	·023	19·07	1·24	4·93
	40	18 1·77	3·53		17·83	1·25	4·85
	50	17 58·24	3·54		16·58	1·24	4·78
64	0	+17 54·70	3·55	+·022	−1 15·34	1·24	+4·70
	10	17 51·15	3·56		14·10	1·25	4·63
	20	17 47·59	3·57		12·85	1·24	4·55
	30	17 44·02	3·59	·021	11·61	1·24	4·47
	40	17 40·43	3·59		10·37	1·25	4·40
	50	17 36 84	3·61		9·12	1·25	4·32
65	0	+17 33·23	3·61	+·020	−1 7·87	1·25	+4·25
	10	17 29·62	3·62		6·62	1·24	4·17
	20	17 26·00	3·64		5·38	1·25	4·10
	30	17 22·36	3·64	·019	4·13	1·25	4·02
	40	17 18·72	3·66		2·88	1·25	3·94
	50	17 15·06	3·66		1·63	1·25	3·87
66	0	+17 11·40	3·68	+·017	−1 0·38	1·25	+3·79
	10	17 7·72	3·68		0 59·13	1·25	3·71
	20	17 4·04	3·70		57·88	1·25	3·64
	30	17 0·34	3·71	·016	56·63	1·25	3·56
	40	16 56·63	3·71		55·38	1·25	3·48
	50	16 52·92	3·73		54·13	1·26	3·40
67	0	+16 49·19	3·73	+·015	−0 52·87	1·25	+3·33
	10	16 45·46	3·75		51·62	1·25	3·25
	20	16 41·71	3·75		50·37	1·26	3·17
	30	16 37·96	3·77	·014	49·11	1·25	3·09
	40	16 34·19	3·77		47·86	1·25	3·01
	50	16 30·42	3·78		46·61	1·26	2·94
68	0	+16 26·64	3·80	+·013	−0 45·35	1·26	+2·86
	10	16 22·84	3·80		44·09	1·25	2·78
	20	16 19·04	3·81		42·84	1·26	2·70
	30	16 15·23	3·83	·012	41·58	1·25	2·62
	40	16 11·40	3·83		40·33	1·26	2·54
	50	16 7·57	3·84		39·07	1·26	2·46
69	0	+16 3·73	3·85	+·011	−0 37·81	1·26	+2·39
	10	15 59·88	3·86		36·55	1·26	2·31
	20	15 56·02	3·87		35·29	1·25	2·23
	30	15 52·15	3·88	·010	34·04	1·26	2·15
	40	15 48·27	3·89		32·78	1·26	2·07
	50	15 44·38	3·90		31·52	1·26	1·99
70	0	+15 40·48		+·009	−0 30·26		+1·91

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
70°	0′	+15° 40′·48	3·91	+·009	−0° 30′·26	1·25	+1′·91
	10	15 36·57	3·91		29·01	1·26	1·83
	20	15 32·66	3·93		27·75	1·26	1·75
	30	15 28·73	3·93	·008	26·49	1·26	1·67
	40	15 24·80	3·95		25·23	1·26	1·60
	50	15 20·85	3·95		23·97	1·26	1·52
71	0	+15 16·90	3·96	+·007	−0 22·71	1·26	+1·44
	10	15 12·94	3·97		21·45	1·26	1·36
	20	15 8·97	3·98		20·19	1·27	1·28
	30	15 4·99	3·99	·005	18·92	1·26	1·20
	40	15 1·00	4·00		17·66	1·26	1·12
	50	14 57·00	4·00		16·40	1·26	1·04
72	0	+14 53·00	4·02	+·004	−0 15·14	1·26	+0·96
	10	14 48·98	4·02		13·88	1·26	0·88
	20	14 44·96	4·03		12·62	1·26	0·80
	30	14 40·93	4·04	·003	11·36	1·26	0·72
	40	14 36·89	4·05		10·10	1·27	0·64
	50	14 32·84	4·06		8·83	1·26	0·56
73	0	+14 28·78	4·07	+·002	−0 7·57	1·26	+0·48
	10	14 24·71	4·08		6·31	1·26	0·40
	20	14 20·63	4·08		5·05	1·26	0·32
	30	14 16·55	4·09	+·001	3·79	1·27	0·24
	40	14 12·46	4·10		2·52	1·26	0·16
	50	14 8·36	4·11		− 1·26	1·26	+0·08
74	0	+14 4·25	4·12	·000	0 0·00	1·26	0·00
	10	14 0·13	4·12		+ 1·26	1·26	−0·08
	20	13 56·01	4·13		2·52	1·27	0·16
	30	13 51·88	4·14	−·001	3·79	1·26	0·24
	40	13 47·74	4·15		5·05	1·26	0·32
	50	13 43·59	4·16		6·31	1·26	0·40
75	0	+13 39·43	4·17	−·002	+0 7·57	1·26	−0·48
	10	13 35·26	4·17		8·83	1·27	0·56
	20	13 31·09	4·18		10·10	1·26	0·64
	30	13 26·91	4·19	·003	11·36	1·26	0·72
	40	13 22·72	4·19		12·62	1·26	0·80
	50	13 18·53	4·21		13·88	1·26	0·88
76	0	+13 14·32	4·21	−·004	+0 15·14	1·26	−0·96
	10	13 10·11	4·22		16·40	1·26	1·04
	20	13 5·89	4·23		17·66	1·26	1·12
	30	13 1·66	4·23	·005	18·92	1·27	1·20
	40	12 57·43	4·25		20·19	1·26	1·28
	50	12 53·18	4·25		21·45	1·26	1·36
77	0	+12 48·93	4·26	−·007	+0 22·71	1·26	−1·44
	10	12 44·67	4·26		23·97	1·26	1·52
	20	12 40·41	4·27		25·23	1·26	1·60
	30	12 36·14	4·28	·008	26·49	1·26	1·67
	40	12 31·86	4·29		27·75	1·26	1·75
	50	12 27·57	4·29		29·01	1·25	1·83
78	0	+12 23·28	4·30	−·009	+0 30·26	1·26	−1·91
	10	12 18·98	4·31		31·52	1·26	1·99
	20	12 14·67	4·32		32·78	1·26	2·07
	30	12 10·35	4·32	·010	34·04	1·25	2·15
	40	12 6·03	4·33		35·29	1·26	2·23
	50	12 1·70	4·34		36·55	1·26	2·31
79	0	+11 57·36	4·34	−·011	+0 37·81	1·26	−2·39
	10	11 53·02	4·35		39·07	1·26	2·46
	20	11 48·67	4·36		40·33	1·25	2·54
	30	11 44·31	4·36	·012	41·58	1·26	2·62
	40	11 39·95	4·37		42·84	1·25	2·70
	50	11 35·58	4·38		44·09	1·26	2·78
80	0	+11 31·20		−·013	+0 45·35		−2·86

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
80° 0′	+11° 31′·20	4·38	−·013ν	+0° 45′·35	1·26	− 2′·86
10	11 26·82	4·39		46·61	1·25	2·94
20	11 22·43	4·40		47·86	1·25	3·01
30	11 18·03	4·40	·014	49·11	1·26	3·09
40	11 13·63	4·41		50·37	1·25	3·17
50	11 9·22	4·42		51·62	1·25	3·25
81 0	+11 4·80	4·42	−·015	+0 52·87	1·26	− 3·33
10	11 0·38	4·43		54·13	1·25	3·40
20	10 55·95	4·43		55·38	1·25	3·48
30	10 51·52	4·44	·016	56·63	1·25	3·56
40	10 47·08	4·45		57·88	1·25	3·64
50	10 42·63	4·45		0 59·13	1·25	3·71
82 0	+10 38·18	4·46	−·017	+1 0·38	1·25	− 3·79
10	10 33·72	4·47		1·63	1·25	3·87
20	10 29·25	4·47		2·88	1·25	3·94
30	10 24·78	4·48	·019	4·13	1·25	4·02
40	10 20·30	4·48		5·38	1·24	4·10
50	10 15·82	4·48		6·62	1·25	4·17
83 0	+10 11·34	4·50	−·020	+1 7·87	1·25	− 4·25
10	10 6·84	4·50		9·12	1·25	4·32
20	10 2·34	4·50		10·37	1·24	4·40
30	9 57·84	4·51	·021	11·61	1·24	4·47
40	9 53·33	4·52		12·85	1·25	4·55
50	9 48·81	4·52		14·10	1·24	4·63
84 0	+ 9 44·29	4·53	−·022	+1 15·34	1·24	− 4·70
10	9 39·76	4·53		16·58	1·25	4·78
20	9 35·23	4·54		17·83	1·24	4·85
30	9 30·69	4·54	·023	19·07	1·24	4·93
40	9 26·15	4·55		20·31	1·24	5·00
50	9 21·60	4·55		21·55	1·24	5·07
85 0	+ 9 17·05	4·56	−·024	+1 22·79	1·24	− 5·15
10	9 12·49	4·56		24·03	1·24	5·22
20	9 7·93	4·57		25·27	1·23	5·30
30	9 3·36	4·57	·025	26·50	1·23	5·37
40	8 58·79	4·58		27·73	1·24	5·44
50	8 54·21	4·59		28·97	1·24	5·52
86 0	+ 8 49·62	4·59	−·026	+1 30·21	1·24	− 5·59
10	8 45·03	4·59		31·45	1·23	5·66
20	8 40·44	4·59		32·68	1·23	5·74
30	8 35·85	4·60	·027	33·91	1·23	5·81
40	8 31·25	4·61		35·14	1·24	5·88
50	8 26·64	4·61		36·38	1·23	5·95
87 0	+ 8 22·03	4·62	−·028	+1 37·61	1·23	− 6·03
10	8 17·41	4·62		38·84	1·22	6·10
20	8 12·79	4·62		40·06	1·23	6·17
30	8 8·17	4·63	·029	41·29	1·23	6·24
40	8 3·54	4·63		42·52	1·23	6·31
50	7 58·91	4·64		43·75	1·22	6·38
88 0	+ 7 54·27	4·64	−·030	+1 44·97	1·23	− 6·45
10	7 49·63	4·65		46·20	1·22	6·53
20	7 44·98	4·65		47·42	1·22	6·60
30	7 40·33	4·65	·031	48·64	1·22	6·67
40	7 35·68	4·66		49·86	1·23	6·74
50	7 31·02	4·66		51·09	1·22	6·81
89 0	+ 7 26·36	4·66	−·032	+1 52·31	1·22	− 6·87
10	7 21·70	4·67		53·53	1·21	6·94
20	7 17·03	4·67		54·74	1·22	7·01
30	7 12·36	4·68	·033	55·96	1·22	7·08
40	7 7·68	4·68		57·18	1·21	7·15
50	7 3·00	4·68		58·39	1·22	7·22
90 0	+ 6 58·32		−·035ν	+1 59·61		− 7·29

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
90° 0′	+ 6° 58′·32	4·69	−·035ν	+1° 59′·61	1·21	− 7′·29
10	6 53·63	4·69		2 0·82	1·21	7·35
20	6 48·94	4·69		2·03	1·21	7·42
30	6 44·25	4·70	·036	3·24	1·21	7·49
40	6 39·55	4·70		4·45	1·21	7·56
50	6 34·85	4·71		5·66	1·21	7·63
91 0	+ 6 30·15	4·71	−·037	+2 6·87	1·21	− 7·69
10	6 25·44	4·71		8·08	1·21	7·76
20	6 20·73	4·71		9·29	1·20	7·82
30	6 16·02	4·72	·038	10·49	1·20	7·89
40	6 11·30	4·72		11·69	1·21	7·95
50	6 6·58	4·72		12·90	1·20	8·02
92 0	+ 6 1·86	4·72	−·039	+2 14·10	1·20	− 8·08
10	5 57·14	4·73		15·30	1·20	8·15
20	5 52·41	4·73		16·50	1·20	8·21
30	5 47·68	4·73	·040	17·70	1·20	8·28
40	5 42·95	4·74		18·90	1·19	8·34
50	5 38·21	4·74		20·09	1·19	8·40
93 0	+ 5 33·47	4·74	−·041	+2 21·28	1·20	− 8·47
10	5 28·73	4·74		22·48	1·19	8·53
20	5 23·99	4·75		23·67	1·19	8·59
30	5 19·24	4·75	·042	24·86	1·19	8·66
40	5 14·49	4·75		26·05	1·19	8·72
50	5 9·74	4·75		27·24	1·19	8·78
94 0	+ 5 4·99	4·75	−·043	+2 28·43	1·18	− 8·84
10	5 0·24	4·76		29·61	1·19	8·90
20	4 55·48	4·76		30·80	1·18	8·96
30	4 50·72	4·76	·044	31·98	1·19	9·03
40	4 45·96	4·77		33·17	1·18	9·09
50	4 41·19	4·76		34·35	1·18	9·15
95 0	+ 4 36·43	4·77	−·045	+2 35·53	1·18	− 9·21
10	4 31·66	4·77		36·71	1·18	9·26
20	4 26·89	4·77		37·89	1·17	9·32
30	4 22·12	4·77	·046	39·06	1·17	9·38
40	4 17·35	4·77		40·23	1·18	9·44
50	4 12·58	4·78		41·41	1·17	9·50
96 0	+ 4 7·80	4·78	−·047	+2 42·58	1·17	− 9·56
10	4 3·02	4·78		43·75	1·17	9·61
20	3 58·24	4·78		44·92	1·17	9·67
30	3 53·46	4·78	·048	46·09	1·17	9·73
40	3 48·68	4·79		47·26	1·16	9·79
50	3 43·89	4·78		48·42	1·16	9·84
97 0	+ 3 39·11	4·79	−·049	+2 49·58	1·17	− 9·90
10	3 34·32	4·78		50·75	1·16	9·95
20	3 29·54	4·79		51·91	1·16	10·01
30	3 24·75	4·79	·050	53·07	1·16	10·06
40	3 19·96	4·79		54·23	1·15	10·12
50	3 15·17	4·79		55·38	1·16	10·17
98 0	+ 3 10·38	4·80	−·051	+2 56·54	1·15	−10·23
10	3 5·58	4·79		2 57·69	1·15	10·28
20	3 0·79	4·79		2 58·84	1·15	10·33
30	2 56·00	4·80	·052	2 59·99	1·15	10·39
40	2 51·20	4·80		3 1·14	1·15	10·44
50	2 46·40	4·79		3 2·29	1·15	10·49
99 0	+ 2 41·61	4·80	−·053	+3 3·44	1·14	−10·54
10	2 36·81	4·80		4·58	1·14	10·59
20	2 32·01	4·80		5·72	1·14	10·64
30	2 27·21	4·80	·054	6·86	1·14	10·70
40	2 22·41	4·79		8·00	1·14	10·75
50	2 17·62	4·80		9·14	1·14	10·80
100 0	+ 2 12·82		−·055ν	+3 10·28		−10·85

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
°	′	° ′			° ′		′
100	0	+2 12·82	4·80	—·055ν	+3 10·28	1·13	—10·85
	10	2 8·02	4·80		11·41	1·14	10·89
	20	2 3·22	4·81		12·55	1·13	10·94
	30	1 58·41	4·80	·056	13·68	1·13	10·99
	40	1 53·61	4·80		14·81	1·13	11·04
	50	1 48·81	4·80		15·94	1·13	11·09
101	0	+1 44·01	4·80	—·057	+3 17·07	1·12	—11·14
	10	1 39·21	4·80		18·19	1·13	11·18
	20	1 34·41	4·80		19·32	1·12	11·23
	30	1 29·61	4·80	·058	20·44	1·12	11·28
	40	1 24·81	4·80		21·56	1·12	11·32
	50	1 20·01	4·80		22·68	1·11	11·37
102	0	+1 15·21	4·80	—·059	+3 23·79	1·12	—11·41
	10	1 10·41	4·80		24·91	1·11	11·46
	20	1 5·61	4·80		26·02	1·12	11·50
	30	1 0·81	4·80	·060	27·14	1·11	11·55
	40	0 56·01	4·80		28·25	1·10	11·59
	50	0 51·21	4·80		29·35	1·11	11·63
103	0	+0 46·41	4·79	—·061	+3 30·46	1·11	—11·68
	10	0 41·62	4·80		31·57	1·10	11·72
	20	0 37·82	4·80		32·67	1·10	11·76
	30	0 32·02	4·79	·062	33·77	1·10	11·80
	40	0 27·23	4·80		34·87	1·10	11·84
	50	0 22·43	4·79		35·97	1·09	11·88
104	0	+0 17·64	4·79	—·063	+3 37·06	1·10	—11·92
	10	0 12·85	4·79		38·16	1·09	11·96
	20	0 8·06	4·79		39·25	1·09	12·00
	30	+0 3·27	4·79	·064	40·34	1·09	12·04
	40	—0 1·52	4·79		41·43	1·09	12·08
	50	0 6·31	4·79		42·52	1·08	12·12
105	0	—0 11·10	4·79	—·065	+3 43·60	1·09	—12·16
	10	0 15·89	4·78		44·69	1·08	12·20
	20	0 20·67	4·79		45·77	1·08	12·23
	30	0 25·46	4·78	·066	46·85	1·07	12·27
	40	0 30·24	4·78		47·92	1·08	12·31
	50	0 35·02	4·78		49·00	1·07	12·34
106	0	—0 39·80	4·78	—·067	+3 50·07	1·07	—12·38
	10	0 44·58	4·77		51·14	1·07	12·41
	20	0 49·35	4·78		52·21	1·07	12·45
	30	0 54·13	4·77	·068	53·28	1·07	12·48
	40	0 58·90	4·77		54·35	1·06	12·52
	50	1 3·67	4·77		55·41	1·06	12·55
107	0	—1 8·44	4·77	—·069	+3 56·47	1·06	—12·58
	10	1 13·21	4·77		3 57·53	1·06	12·62
	20	1 17·98	4·76		3 58·59	1·06	12·65
	30	1 22·74	4·77	·069	3 59·65	1·05	12·68
	40	1 27·51	4·76		4 0·70	1·05	12·71
	50	1 32·27	4·76		4 1·75	1·05	12·74
108	0	—1 37·03	4·75	—·070	+4 2·80	1·05	—12·77
	10	1 41·78	4·76		3·85	1·05	12·80
	20	1 46·54	4·75		4·90	1·04	12·83
	30	1 51·29	4·75	·071	5·94	1·04	12·86
	40	1 56·04	4·75		6·98	1·04	12·89
	50	2 0·79	4·74		8·02	1·04	12·92
109	0	—2 5·53	4·75	—·072	+4 9·06	1·03	—12·95
	10	2 10·28	4·74		10·09	1·04	12·97
	20	2 15·02	4·74		11·13	1·03	13·00
	30	2 19·76	4·73	·073	12·16	1·03	13·03
	40	2 24·49	4·74		13·19	1·02	13·06
	50	2 29·23	4·73		14·21	1·03	13·08
110	0	—2 33·96		—·074ν	+4 15·24		—13·11

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
°	′	° ′			° ′		′
110	0	—2 33·96	4·73	—·074ν	+4 15·24	1·02	—13·11
	10	2 38·69	4·72		16·26	1·02	13·13
	20	2 43·41	4·73		17·28	1·02	13·16
	30	2 48·14	4·72	·075	18·30	1·02	13·18
	40	2 52·86	4·71		19·32	1·01	13·20
	50	2 57·57	4·72		20·33	1·01	13·23
111	0	—3 2·29	4·71	—·076	+4 21·34	1·01	—13·25
	10	3 7·00	4·71		22·35	1·01	13·27
	20	3 11·71	4·71		23·36	1·01	13·29
	30	3 16·42	4·70	·077	24·37	1·00	13·31
	40	3 21·12	4·70		25·37	1·00	13·33
	50	3 25 82	4·70		26·37	1·00	13·35
112	0	—3 30 52	4·69	—·078	+4 27·37	1·00	—13·37
	10	3 35·21	4·69		28·37	0·99	13·39
	20	3 39·90	4·69		29·36	·99	13·41
	30	3 44·59	4·68	·078	30·35	·99	13·43
	40	3 49·27	4·68		31·34	·99	13·45
	50	3 53·95	4·68		32·33	·98	13·47
113	0	—3 58·63	4·67	—·079	+4 33·31	·99	—13·49
	10	4 3·30	4·67		34·30	·98	13·50
	20	4 7·97	4·67		35·28	·97	13·52
	30	4 12·64	4·67	·080	36·25	·98	13·53
	40	4 17·31	4·66		37·23	·97	13·55
	50	4 21·97	4·65		38·20	·97	13·56
114	0	—4 26·62	4·65	—·081	+4 39·17	·97	—13·58
	10	4 31·27	4·65		40·14	·97	13·59
	20	4 35·92	4·65		41·11	·96	13·61
	30	4 40·57	4·64	·082	42·07	·96	13·62
	40	4 45·21	4·64		43·03	·96	13·63
	50	4 49·85	4·63		43·99	·96	13·64
115	0	—4 54·48	4·63	—·083	+4 44·95	·96	—13·66
	10	4 59·11	4·63		45·91	·95	13·67
	20	5 3·74	4·62		46·86	·95	13·68
	30	5 8·36	4·62	·084	47·81	·94	13·69
	40	5 12·98	4·61		48·75	·95	13·70
	50	5 17·59	4·61		49·70	·94	13·71
116	0	—5 22·20	4·61	—·084	+4 50·64	·94	—13·72
	10	5 26·81	4·60		51·58	·94	13·72
	20	5 31·41	4·60		52·52	·93	13·73
	30	5 36·01	4·59	·085	53·45	·94	13·74
	40	5 40·60	4·59		54·39	·93	13·75
	50	5 45·19	4·58		55·32	·92	13·75
117	0	—5 49·77	4·58	—·086	+4 56·24	·93	—13·76
	10	5 54·35	4·58		4 57·17	·92	13·77
	20	5 58·93	4·57		4 58·09	·92	13·77
	30	6 3·50	4·57	·087	4 59·01	·92	13·78
	40	6 8·07	4·56		4 59·93	·92	13·78
	50	6 12·63	4·55		5 0·85	·91	13·78
118	0	—6 17·18	4·56	—·088	+5 1·76	·91	—13·79
	10	6 21·74	4·55		2·67	·91	13·79
	20	6 26·29	4·54		3·58	·90	13·79
	30	6 30·83	4·54	·088	4·48	·90	13·79
	40	6 35·37	4·53		5·38	·90	13·80
	50	6 39·90	4·53		6·28	·90	13·80
119	0	—6 44·43	4·53	—·089	+5 7·18	·90	—13·80
	10	6 48·96	4·52		8·08	·89	13·80
	20	6 53·48	4·51		8·97	·89	13·80
	30	6 57·99	4·51	·090	9·86	·88	13·80
	40	7 2·50	4·50		10·74	·89	13·80
	50	7 7·00	4·50		11·63	0·88	13·79
120	0	—7 11·50		—·091ν	+5 12·51		—13·79

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
°	′	° ′			° ′		′
120	0	− 7 11·50	4·50	−·091ν	+5 12·51	0·88	−13·79
	10	7 16·00	4·49		13·39	·88	13·79
	20	7 20·49	4·48		14·27	·87	13·79
	30	7 24·97	4·48	·092	15·14	·87	13·78
	40	7 29·45	4·47		16·01	·87	13·78
	50	7 33·92	4·47		16·88	·86	13·77
121	0	− 7 38·39	4·47	−·092	+5 17·74	·87	−13·77
	10	7 42·86	4·46		18·61	·86	13·76
	20	7 47·32	4·45		19·47	·85	13·76
	30	7 51·77	4·45	·093	20·32	·86	13·75
	40	7 56·22	4·44		21·18	·85	13·74
	50	8 0·66	4·44		22·03	·85	13·74
122	0	− 8 5·10	4·43	−·094	+5 22·88	·85	−13·73
	10	8 9·53	4·42		23·73	·84	13·72
	20	8 13·95	4·42		24·57	·84	13·71
	30	8 18·37	4·42	·095	25·41	·84	13·70
	40	8 22·79	4·41		26·25	·84	13·69
	50	8 27·20	4·40		27·09	·83	13·68
123	0	− 8 31·60	4·40	−·095	+5 27·92	·83	−13·67
	10	8 36·00	4·39		28·75	·83	13·66
	20	8 40·39	4·38		29·58	·82	13·65
	30	8 44·77	4·38	·096	30·40	·83	13·64
	40	8 49·15	4·38		31·23	·82	13·62
	50	8 53·53	4·37		32·05	·81	13·61
124	0	− 8 57·90	4·36	−·097	+5 32·86	·81	−13·60
	10	9 2·26	4·36		33·67	·81	13·58
	20	9 6·62	4·35		34·48	·81	13·57
	30	9 10·97	4·34	·098	35·29	·81	13·55
	40	9 15·31	4·34		36·10	·80	13·54
	50	9 19·65	4·33		36·90	·80	13·52
125	0	− 9 23·98	4·33	−·098	+5 37·70	·80	−13·51
	10	9 28·31	4·32		38·50	·79	13·49
	20	9 32·63	4·31		39·29	·79	13·47
	30	9 36·94	4·31	·099	40·08	·79	13·46
	40	9 41·25	4·30		40·87	·78	13·44
	50	9 45·55	4·30		41·65	·77	13·42
126	0	− 9 49·85	4·29	−·100	+5 42·44	·78	−13·40
	10	9 54·14	4·28		43·22	·77	13·38
	20	9 58·42	4·28		43·99	·78	13·36
	30	10 2·70	4·27	·100	44·77	·77	13·34
	40	10 6·97	4·26		45·54	·77	13·32
	50	10 11·23	4·26		46·31	·76	13·30
127	0	−10 15·49	4·25	−·101	+5 47·07	·76	−13·28
	10	10 19·74	4·25		47·83	·76	13·26
	20	10 23·99	4·24		48·59	·76	13·23
	30	10 28·23	4·23	·102	49·35	·75	13·21
	40	10 32·46	4·22		50·10	·75	13·19
	50	10 36·68	4·22		50·85	·75	13·16
128	0	−10 40·90	4·21	−·102	+5 51·60	·74	−13·14
	10	10 45·11	4·21		52·34	·74	13·11
	20	10 49·32	4·20		53·08	·74	13·09
	30	10 53·52	4·19	·103	53·82	·73	13·06
	40	10 57·71	4·18		54·55	·74	13·04
	50	11 1·89	4·18		55·29	·73	13·01
129	0	−11 6·07	4·17	−·104	+5 56·02	·72	−12·98
	10	11 10·24	4·17		56·74	·73	12·96
	20	11 14·41	4·16		57·47	·72	12·93
	30	11 18·57	4·15	·104	58·19	·71	12·90
	40	11 22·72	4·14		58·90	·72	12·87
	50	11 26·86	4·14		5 59·62	0·71	12·84
130	0	−11 31·00		−·105ν	+6 0·33		−12·81

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
°	′	° ′			° ′		′
130	0	−11 31·00	4·13	−·105ν	+6 0·33	0·71	−12·81
	10	11 35·13	4·12		1·04	·70	12·78
	20	11 39·25	4·12		1·74	·70	12·75
	30	11 43·37	4·11	·106	2·44	·70	12·72
	40	11 47·48	4·10		3·14	·70	12·69
	50	11 51·58	4·09		3·84	·69	12·66
131	0	−11 55·67	4·09	−·106	+6 4·53	·69	−12·63
	10	11 59·76	4·08		5·22	·69	12·59
	20	12 3·84	4·08		5·91	·68	12·56
	30	12 7·92	4·06	·107	6·59	·68	12·53
	40	12 11·98	4·06		7·27	·68	12·49
	50	12 16·04	4·05		7·95	·67	12·46
132	0	−12 20·09	4·05	−·107	+6 8·62	·67	−12·42
	10	12 24·14	4·03		9·29	·67	12·39
	20	12 28·17	4·03		9·96	·67	12·35
	30	12 32·20	4·03	·108	10·63	·66	12·32
	40	12 36·23	4·01		11·29	·66	12·28
	50	12 40·24	4·01		11·95	·65	12·24
133	0	−12 44·25	4·00	−·109	+6 12·60	·65	−12·21
	10	12 48·25	3·99		13·25	·65	12·17
	20	12 52·24	3·99		13·90	·65	12·13
	30	12 56·23	3·98	·109	14·55	·64	12·09
	40	13 0·21	3·97		15·19	·64	12·05
	50	13 4·18	3·96		15·83	·64	12·01
134	0	−13 8·14	3·95	−·110	+6 16·47	·63	−11·97
	10	13 12·09	3·95		17·10	·63	11·93
	20	13 16·04	3·94		17·73	·63	11·89
	30	13 19·98	3·93	·110	18·36	·62	11·85
	40	13 23·91	3·93		18·98	·62	11·81
	50	13 27·84	3·91		19·60	·62	11·77
135	0	−13 31·75	3·91	−·111	+6 20·22	·61	−11·73
	10	13 35·66	3·90		20·83	·61	11·68
	20	13 39·56	3·90		21·44	·61	11·64
	30	13 43·46	3·88	·111	22·05	·61	11·60
	40	13 47·34	3·88		22·66	·60	11·55
	50	13 51·22	3·87		23·26	·60	11·51
136	0	−13 55·09	3·86	−·112	+6 23·86	·59	−11·46
	10	13 58·95	3·86		24·45	·59	11·42
	20	14 2·81	3·84		25·04	·59	11·37
	30	14 6·65	3·84	·112	25·63	·58	11·33
	40	14 10·49	3·83		26·21	·58	11·28
	50	14 14·32	3·82		26·79	·58	11·24
137	0	−14 18·14	3·82	−·113	+6 27·37	·58	−11·19
	10	14 21·96	3·81		27·95	·57	11·14
	20	14 25·77	3·79		28·52	·57	11·09
	30	14 29·56	3·79	·113	29·09	·56	11·05
	40	14 33·35	3·79		29·65	·56	11·00
	50	14 37·14	3·77		30·21	·56	10·95
138	0	−14 40·91	3·77	−·114	+6 30·77	·56	−10·90
	10	14 44·68	3·75		31·33	·55	10·85
	20	14 48·43	3·75		31·88	·55	10·80
	30	14 52·18	3·75	·114	32·43	·55	10·75
	40	14 55·93	3·73		32·98	·54	10·70
	50	14 59·66	3·72		33·52	·54	10·65
139	0	−15 3·38	3·72	−·115	+6 34·06	·53	−10·60
	10	15 7·10	3·71		34·59	·53	10·55
	20	15 10·81	3·70		35·12	·53	10·49
	30	15 14·51	3·69	·116	35·65	·53	10·44
	40	15 18·20	3·68		36·18	·52	10·39
	50	15 21·88	3·68		36·70	0·52	10·34
140	0	−15 25·56		−·116ν	+6 37·22		−10·28

☉	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
° ′	° ′			° ′		′
140 0	−15 25·56	3·67	−·116ν	+6 37·22	0·51	−10·28
10	15 29·23	3·66		37·73	·51	10·23
20	15 32·89	3·64		38·24	·51	10·17
30	15 36·53	3·64	·117	38·75	·51	10·12
40	15 40·17	3·64		39·26	·50	10·06
50	15 43·81	3·62		39·76	·50	10·01
141 0	−15 47·43	3·62	−·117	+6 40·26	·49	− 9·95
10	15 51·05	3·60		40·75	·49	9·90
20	15 54·65	3·60		41·24	·49	9·84
30	15 58·25	3·59	·118	41·73	·48	9·78
40	16 1·84	3·59		42·21	·48	9·73
50	16 5·43	3·57		42·69	·48	9·67
142 0	−16 9·00	3·56	−·118	+6 43·17	·48	− 9·61
10	12·56	3·56		43·65	·47	9·55
20	16·12	3·55		44·12	·47	9·50
30	19·67	3·54	·118	44·59	·46	9·44
40	23·31	3·53		45·05	·46	9·38
50	26·84	3·52		45·51	·46	9·32
143 0	−16 30·26	3·51	−·119	+6 45·97	·45	− 9·26
10	33·77	3·50		46·42	·45	9·20
20	37·27	3·50		46·87	·45	9·14
30	40·77	3·48	·119	47·32	·44	9·08
40	44·25	3·48		47·56	·44	9·02
50	47·73	3·47		48·20	·44	8·96
144 0	−16 51·20	3·46	−·119	+6 48·64	·43	− 8·90
10	16 54·66	3·45		49·07	·43	8·83
20	16 58·11	3·44		49·50	·43	8·77
30	17 1·55	3·43	·119	49·93	·42	8·71
40	17 4·98	3·43		50·35	·42	8·65
50	17 8·41	3·41		50·77	·41	8·58
145 0	−17 11·82	3·41	−·120	+6 51·18	·42	− 8·52
10	15·23	3·40		51·60	·41	8·46
20	18·63	3·38		52·01	·40	8·39
30	22·01	3·38	·120	52·41	·40	8·33
40	25·39	3·37		52·81	·40	8·27
50	28·76	3·36		53·21	·39	8·21
146 0	−17 32·12	3·36	−·120	+6 53·60	·39	− 8·14
10	35·48	3·34		53·99	·39	8·07
20	38·82	3·33		54·38	·39	8·01
30	42·15	3·33	·121	54·77	·38	7·94
40	45·48	3·31		55·15	·37	7·87
50	48·79	3·31		55·52	·38	7·81
147 0	−17 52·10	3·30	−·121	+6 55·90	·37	− 7·74
10	17 55·40	3·29		56·27	·36	7·67
20	17 58·69	3·27		56·63	·37	7·61
30	18 1·96	3·27	·122	57·00	·36	7·54
40	18 5·23	3·26		57·36	·35	7·47
50	18 8·49	3·26		57·71	·35	7·40
148 0	−18 11·75	3·24	−·122	+6 58·06	·35	− 7·34
10	14·99	3·23		58·41	·35	7·27
20	18·22	3·22		58·76	·34	7·20
30	21·44	3·22	·122	59·10	·34	7·13
40	24·66	3·20		59·44	·33	7·06
50	27·86	3·20		6 59·77	·33	6·99
149 0	−18 31·06	3·18	−·123	+7 0·10	·33	− 6·92
10	34·24	3·18		0·43	·32	6·85
20	37·42	3·17		0·75	·32	6·78
30	40·59	3·16	·123	1·07	·32	6·71
40	43·75	3·15		1·39	·31	6·64
50	46·90	3·14		1·70	0·31	6·57
150 0	−18 50·04		−·123ν	+7 2·01		− 6·50

☉	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
° ′	° ′			° ′		′
150 0	−18 50·04	3·13	−·123ν	+7 2·01	0·31	− 6·50
10	18 53·17	3·12		2·32	·30	6·43
20	18 56·29	3·11		2·62	·30	6·36
30	18 59·40	3·10	·124	2·92	·29	6·29
40	19 2·50	3·09		3·21	·29	6·21
50	19 5·59	3·08		3·50	·29	6·14
151 0	−19 8·67	3·07	−·124	+7 3·79	·29	− 6·07
10	11·74	3·07		4·08	·28	6·00
20	14·81	3·05		4·36	·27	5·93
30	17·86	3·04	·124	4·63	·28	5·85
40	20·90	3·04		4·91	·27	5·78
50	23·94	3·02		5·18	·26	5·71
152 0	−19 26·96	3·02	−·124	+7 5·44	·27	− 5·63
10	29·98	3·00		5·71	·26	5·56
20	32·98	3·00		5·97	·25	5·48
30	35·98	2·99	·125	6·22	·25	5·41
40	38·97	2·97		6·47	·25	5·34
50	41·94	2·97		6·72	·25	5·26
153 0	−19 44·91	2·96	−·125	+7 6·97	·24	− 5·19
10	19 47·87	2·94		7·21	·23	5·11
20	19 50·81	2·94		7·44	·24	5·04
30	19 53·75	2·93	·125	7·68	·23	4·96
40	19 56·68	2·92		7·91	·22	4·89
50	19 59·60	2·91		8·13	·23	4·81
154 0	−20 2·51	2·89	−·125	+7 8·36	·22	− 4·74
10	5·40	2·89		8·58	·21	4·66
20	8·29	2·88		8·79	·21	4·59
30	11·17	2·87	·125	9·00	·21	4·51
40	14·04	2·86		9·21	·21	4·43
50	16·90	2·85		9·42	·20	4·36
155 0	−20 19·75	2·84	−·126	+7 9·62	·19	− 4·28
10	22·59	2·83		9·81	·20	4·20
20	25·42	2·82		10·01	·19	4·13
30	28·24	2·81	·126	10·20	·18	4·05
40	31·05	2·80		10·38	·18	3·97
50	33·85	2·79		10·56	·18	3·90
156 0	−20 36·64	2·78	−·126	+7 10·74	·18	− 3·82
10	39·42	2·77		10·92	·17	3·74
20	42·19	2·76		11·09	·17	3·66
30	44·95	2·75	·126	11·26	·16	3·59
40	47·70	2·74		11·42	·16	3·51
50	50·44	2·72		11·58	·16	3·43
157 0	−20 53·16	2·72	−·126	+7 11·74	·15	− 3·35
10	20 55·88	2·71		11·89	·15	3·27
20	20 58·59	2·70		12·04	·15	3·19
30	21 1·29	2·69	·126	12·19	·14	3·12
40	21 3·98	2·68		12·33	·14	3·04
50	21 6·66	2·67		12·47	·13	2·96
158 0	−21 9·33	2·66	−·126	+7 12·60	·13	− 2·88
10	11·99	2·65		12·73	·13	2·80
20	14·64	2·64		12·86	·13	2·72
30	17·28	2·62	·127	12·99	·12	2·64
40	19·90	2·62		13·11	·11	2·56
50	22·52	2·61		13·22	·12	2·48
159 0	−21 25·13	2·60	−·127	+7 13·34	·11	− 2·41
10	27·73	2·59		13·45	·10	2·33
20	30·32	2·58		13·55	·10	2·25
30	32·90	2·56	·127	13·65	·10	2·17
40	35·46	2·56		13·75	·09	2·09
50	38·02	2·55		13·84	0·09	2·01
160 0	−21 40·57		−·127ν	+7 13·93		− 1·93

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.	⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
160° 0′	−21° 40′·57	2·53	−·127ν	+7° 13′·93	0·09	−1′·93	170° 0′	−23° 54′·09	1·90	−·126ν	+7° 12′·60	0·13	+2′·88
10	43·10	2·53		14·02	·08	1·85	10	23 55·99	1·89		12·47	·14	2·96
20	45·63	2·51		14·10	·08	1·77	20	23 57·88	1·87		12·33	·14	3·04
30	48·14	2·51		14·18	·08	1·69	30	23 59·75	1·86	·126	12·19	·15	3·12
40	50·65	2·49		14·26	·07	1·61	40	24 1·61	1·86		12·04	·15	3·19
50	53·14	2·49		14·33	·07	1·53	50	24 3·47	1·84		11·89	·15	3·27
161 0	−21 55·63	2·47	−·127	+7 14·40	·07	−1·45	171 0	−24 5·31	1·83	−·126	+7 11·74	·16	+3·35
10	21 58·10	2·47		14·47	·06	1·37	10	7·14	1·82		11·58	·16	3·43
20	22 0·57	2·45		14·53	·05	1·29	20	8·96	1·81		11·42	·16	3·51
30	22 3·02	2·45		14·58	·06	1·21	30	10·77	1·79	·126	11·26	·17	3·59
40	22 5·47	2·43		14·64	·05	1·13	40	12·56	1·79		11·09	·17	3·66
50	22 7·90	2·42		14·69	·04	1·05	50	14·35	1·77		10·92	·18	3·74
162 0	−22 10·32	2·41	−·127	+7 14·73	·05	−0·97	172 0	−24 16·12	1·77	−·126	+7 10·74	·18	+3·82
10	12·73	2·40		14·78	·04	·89	10	17·89	1·75		10·56	·18	3·90
20	15·13	2·39		14·82	·03	·81	20	19·64	1·74		10·38	·18	3·97
30	17·52	2·39		14·85	·03	·73	30	21·38	1·73	·126	10·20	·19	4·05
40	19·91	2·37		14·88	·03	·64	40	23·11	1·72		10·01	·20	4·13
50	22·28	2·35		14·91	·02	·56	50	24·83	1·71		9·81	·19	4·20
163 0	−22 24·63	2·35	−·127	+7 14·93		−0·48	173 0	−24 26·54	1·69	−·126	+7 9·62	·20	+4·28
10	26·98	2·34		14·95		·40	10	28·23	1·69		9·42	·21	4·36
20	29·32	2·33		14·97		·32	20	29·92	1·67		9·21	·21	4·43
30	31·65	2·32		14·98		·24	30	31·59	1·66	·125	9·00	·21	4·51
40	33·97	2·31		14·99		·16	40	33·25	1·66		8·79	·21	4·59
50	36·28	2·29		15·00		− ·08	50	34·91	1·64		8·58	·22	4·66
164 0	−22 38·57	2·29	−·127	+7 15·00		·00	174 0	−24 36·55	1·63	−·125	+7 8·36	·23	+4·74
10	40·86	2·27		15·00		+ ·08	10	38·18	1·61		8·13	·22	4·81
20	43·13	2·27		14·99		·16	20	39·79	1·61		7·91	·23	4·89
30	45·40	2·25		14·98		·24	30	41·40	1·59	·125	7·68	·24	4·96
40	47·65	2·24		14·97		·32	40	42·99	1·59		7·44	·23	5·04
50	49·89	2·24		14·95		·40	50	44·58	1·57		7·21	·24	5·11
165 0	−22 52·13	2·22	−·127	+7 14·93	·02	+0·48	175 0	−24 46·15	1·56	−·125	+7 6·97	·25	+5·19
10	22 54·35	2·21		14·91	·63	·56	10	47·71	1·55		6·72	·25	5·26
20	22 56·56	2·20		14·88	·03	·64	20	49·26	1·54		6·47	·25	5·34
30	22 58·76	2·19		14·85	·03	·73	30	50·80	1·53	·125	6·22	·25	5·41
40	23 0·95	2·18		14·82	·04	·81	40	52·33	1·51		5·97	·26	5·48
50	23 3·13	2·17		14·78	·05	·89	50	53·84	1·51		5·71	·27	5·56
166 0	−23 5·30	2·15	−·127	+7 14·73	·04	+0·97	176 0	−24 55·35	1·49	−·124	+7 5·44	·26	+5·63
10	7·45	2·15		14·69	·05	1·05	10	24 56·84	1·48		5·18	·27	5·71
20	9·60	2·14		14·64	·06	1·13	20	24 58·32	1·47		4·91	·28	5·78
30	11·74	2·12		14·58	·05	1·21	30	24 59·79	1·46	·124	4·63	·27	5·85
40	13·86	2·12		14·53	·06	1·29	40	25 1·25	1·45		4·36	·28	5·93
50	15·98	2·10		14·47	·07	1·37	50	25 2·70	1·43		4·08	·29	6·00
167 0	−23 18·08	2·09	−·127	+7 14·40	·07	+1·45	177 0	−25 4·13	1·43	−·124	+7 3·79	·29	+6·07
10	20·17	2·09		14·33	·07	1·53	10	5·56	1·41		3·50	·29	6·14
20	22·26	2·07		14·26	·08	1·61	20	6·97	1·40		3·21	·29	6·21
30	24·33	2·06		14·18	·08	1·69	30	8·37	1·39	·124	2·92	·30	6·29
40	26·39	2·05		14·10	·08	1·77	40	9·76	1·38		2·62	·30	6·36
50	28·44	2·04		14·02	·09	1·85	50	11·14	1·36		2·32	·31	6·43
168 0	−23 30·48	2·03	−·127	+7 13·93	·09	+1·93	178 0	−25 12·50	1·36	−·123	+7 2·01	·31	+6·50
10	32·51	2·01		13·84	·09	2·01	10	13·86	1·34		1·70	·31	6·57
20	34·52	2·01		13·75	·10	2·09	20	15·20	1·33		1·39	·32	6·64
30	36·53	2·00		13·65	·10	2·17	30	16·53	1·32	·123	1·07	·32	6·71
40	38·53	1·98		13·55	·10	2·25	40	17·85	1·31		0·75	·32	6·78
50	40·51	1·97		13·45	·11	2·33	50	19·16	1·30		0·43	·33	6·85
169 0	−23 42·48	1·96	−·127	+7 13·34	·12	+2·41	179 0	−25 20·46	1·29	−·123	+7 0·10	·33	+6·92
10	44·44	1·96		13·22	·11	2·48	10	21·75	1·27		6 59·77	·33	6·99
20	46·40	1·94		13·11	·12	2·56	20	23·02	1·26		59·44	·34	7·06
30	48·84	1·93	·127	12·99	·13	2·64	30	24·28	1·25	·122	59·10	·34	7·13
40	50·77	1·92		12·86	·13	2·72	40	25·53	1·24		58·76	·35	7·20
50	52·69	1·90		12·73	0·13	2·80	50	26·77	1·23		58·41	0·35	7·27
170 0	−23 54·09		−·126ν	+7 12·60		+2·88	180 0	−25 28·00		−·122ν	+6 58·06		+7·34

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
180°	0′	−25° 28′·00	1·21	−·122ν	+6° 58′·06	0·35	+ 7′·34
	10	29·21	1·21		57·71	·35	7·40
	20	30·42	1·19		57·36	·36	7·47
	30	31·61	1·18	·122	57·00	·37	7·54
	40	32·79	1·17		56·63	·36	7·61
	50	33·96	1·15		56·27	·37	7·67
181	0	−25 35·11	1·15	−·121	+6 55·90	·38	+ 7·74
	10	36·26	1·13		55·52	·37	7·81
	20	37·39	1·13		55·15	·38	7·87
	30	38·52	1·11	·121	54·77	·39	7·94
	40	39·63	1·09		54·38	·39	8·01
	50	40·72	1·09		53·99	·39	8·07
182	0	−25 41·81	1·08	−·120	+6 53·60	·39	+ 8·14
	10	42·89	1·06		53·21	·40	8·21
	20	43·95	1·05		52·81	·40	8·27
	30	45·00	1·04	·120	52·41	·40	8·33
	40	46·04	1·03		52·01	·41	8·39
	50	47·07	1·01		51·60	·42	8·46
183	0	−25 48·08	1·00	−·120	+6 51·18	·41	+ 8·52
	10	49·08	1·00		50·77	·42	8·58
	20	50·08	0·98		50·35	·42	8·65
	30	51·06	·96	·119	49·93	·43	8·71
	40	52·02	·96		49·50	·43	8·77
	50	52·98	·94		49·07	·43	8·83
184	0	−25 53·92	·94	−·119	+6 48·64	·44	+ 8·90
	10	54·86	·92		48·20	·44	8·96
	20	55·78	·91		47·76	·44	9·02
	30	56·69	·89	·119	47·32	·45	9·08
	40	57·58	·89		46·87	·45	9·14
	50	58·47	·87		46·42	·45	9·20
185	0	−25 59·34	·86	−·119	+6 45·97	·46	+ 9·26
	10	26 0·20	·85		45·51	·46	9·32
	20	1·05	·83		45·05	·46	9·38
	30	1·88	·83	·118	44·59	·47	9·44
	40	2·71	·81		44·12	·47	9·50
	50	3·52	·80		43·65	·48	9·55
186	0	−26 4·32	·79	−·118	+6 43·17	·48	+ 9·61
	10	5·11	·78		42·69	·48	9·67
	20	5·89	·76		42·21	·48	9·73
	30	6·65	·75	·118	41·73	·49	9·78
	40	7·40	·74		41·24	·49	9·84
	50	8·14	·73		40·75	·49	9·90
187	0	−26 8·87	·72	−·117	+6 40·26	·50	+ 9·95
	10	9·59	·70		39·76	·50	10·01
	20	10·29	·69		39·26	·51	10·06
	30	10·98	·68	·117	38·75	·51	10·12
	40	11·66	·67		38·24	·51	10·17
	50	12·33	·66		37·73	·51	10·23
188	0	−26 12·99	·64	−·116	+6 37·22	·52	+10·28
	10	13·63	·63		36·70	·52	10·34
	20	14·26	·62		36·18	·53	10·39
	30	14·88	·61	·116	35·65	·53	10·44
	40	15·49	·59		35·12	·53	10·49
	50	16·08	·58		34·59	·53	10·55
189	0	−26 16·66	·57	−·115	+6 34·06	·54	+10·60
	10	17·23	·56		33·52	·54	10·65
	20	17·79	·55		32·98	·55	10·70
	30	18·34	·53	·114	32·43	·55	10·75
	40	18·87	·52		31·88	·55	10·80
	50	19·39	0·51		31·33	0·56	10·85
190	0	−26 19·90		−·114ν	+6 30·77		+10·90

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
190°	0′	−26° 19′·90	0·50	−·114ν	+6° 30′·77	0·56	+10′·90
	10	20·40	·48		30·21	·56	10·95
	20	20·88	·47		29·65	·56	11·00
	30	21·35	·46	·113	29·09	·57	11·05
	40	21·81	·45		28·52	·57	11·09
	50	22·26	·43		27·95	·58	11·14
191	0	−26 22·69	·43	−·113	+6 27·37	·58	+11·19
	10	23·12	·41		26·79	·58	11·24
	20	23·53	·40		26·21	·58	11·28
	30	23·93	·38	·112	25·63	·59	11·33
	40	24·31	·37		25·04	·59	11·37
	50	24·68	·36		24·45	·59	11·42
192	0	−26 25·04	·35	−·112	+6 23·86	·60	+11·46
	10	25·39	·34		23·26	·60	11·51
	20	25·73	·32		22·66	·61	11·55
	30	26·05	·32	·111	22·05	·61	11·60
	40	26·37	·30		21·44	·61	11·64
	50	26·67	·28		20·83	·61	11·68
193	0	−26 26·95	·27	−·111	+6 20·22	·62	+11·73
	10	27·22	·27		19·60	·62	11·77
	20	27·49	·25		18·98	·62	11·81
	30	27·74	·23	·110	18·36	·63	11·85
	40	27·97	·23		17·73	·63	11·89
	50	28·20	·21		17·10	·63	11·93
194	0	−26 28·41	·20	−·110	+6 16·47	·64	+11·97
	10	28·61	·19		15·83	·64	12·01
	20	28·80	·17		15·19	·64	12·05
	30	28·97	·16	·109	14·55	·65	12·09
	40	29·13	·15		13·90	·65	12·13
	50	29·28	·14		13·25	·65	12·17
195	0	−26 29·42	·12	−·109	+6 12·60	·65	+12·21
	10	29·54	·11		11·95	·66	12·24
	20	29·65	·10		11·29	·66	12·28
	30	29·75	·09	·108	10·63	·67	12·32
	40	29·84	·07		9·96	·67	12·35
	50	29·91	·06		9·29	·67	12·39
196	0	−26 29·97	·05	−·107	+6 8·62	·67	+12·42
	10	30·02	·04		7·95	·68	12·46
	20	30·06	·02		7·27	·68	12·49
	30	30·08	·01	·107	6·59	·68	12·53
	40	30·09	·00		5·91	·69	12·56
	50	30·09	·01		5·22	·69	12·59
197	0	−26 30·08	·03	−·106	+6 4·53	·69	+12·63
	10	30·05	·04		3·84	·70	12·66
	20	30·01	·05		3·14	·70	12·69
	30	29·96	·06	·106	2·44	·70	12·72
	40	29·90	·08		1·74	·70	12·75
	50	29·82	·09		1·04	·71	12·78
198	0	−26 29·73	·11	−·105	+6 0·33	·71	+12·81
	10	29·62	·11		5 59·62	·72	12·84
	20	29·51	·13		58·90	·71	12·87
	30	29·38	·14	·104	58·19	·72	12·90
	40	29·24	·15		57·47	·73	12·93
	50	29·09	·17		56·74	·72	12·96
199	0	−26 28·92	·18	−·104	+5 56·02	·73	+12·98
	10	28·74	·19		55·29	·74	13·01
	20	28·55	·21		54·55	·73	13·04
	30	28·34	·21	·103	53·82	·74	13·06
	40	28·13	·23		53·08	·74	13·09
	50	27·90	0·25		52·34	0·74	13·11
200	0	−26 27·65		−·102ν	+5 51·60		+13·14

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
200°	0′	−26° 27′·65	0·25	−·102ν	+5° 51′·60	0·75	+13′·14
	10	27·40	·27		50·85	·75	13·16
	20	27·13	·28		50·10	·75	13·19
	30	26·85	·29	·102	49·35	·76	13·21
	40	26·56	·31		48·59	·76	13·23
	50	26·25	·32		47·83	·76	13·26
201	0	−26 25·93	·33	−·101	+5 47·07	·76	+13·28
	10	25·60	·35		46·31	·77	13·30
	20	25·25	·36		45·54	·77	13·32
	30	24·89	·37	·100	44·77	·78	13·34
	40	24·52	·38		43·99	·77	13·36
	50	24·14	·40		43·22	·78	13·38
202	0	−26 23·74	·41	−·100	+5 42·44	·79	+13·40
	10	23·33	·42		41·65	·78	13·42
	20	22·91	·43		40·87	·79	13·44
	30	22·48	·45	·099	40·08	·79	13·46
	40	22·03	·46		39·29	·79	13·47
	50	21·57	·47		38·50	·80	13·49
203	0	−26 21·10	·49	−·098	+5 37·70	·80	+13·51
	10	20·61	·50		36·90	·80	13·52
	20	20·11	·51		36·10	·81	13·54
	30	19·60	·53	·098	35·29	·81	13·55
	40	19·07	·53		34·48	·81	13·57
	50	18·54	·55		33·67	·81	13·58
204	0	−26 17·99	·57	−·097	+5 32·86	·81	+13·60
	10	17·42	·57		32·05	·82	13·61
	20	16·85	·59		31·23	·83	13·62
	30	16·26	·61	·096	30·40	·82	13·64
	40	15·65	·61		29·58	·83	13·65
	50	15·04	·63		28·75	·83	13·66
205	0	−26 14·41	·64	−·095	+5 27·92	·83	+13·67
	10	13·77	·65		27·09	·84	13·68
	20	13·12	·67		26·25	·84	13·69
	30	12·45	·68	·095	25·41	·84	13·70
	40	11·77	·70		24·57	·84	13·71
	50	11·07	·70		23·73	·85	13·72
206	0	−26 10·37	·72	−·094	+5 22·88	·85	+13·73
	10	9·65	·73		22·03	·85	13·74
	20	8·92	·75		21·18	·86	13·74
	30	8·17	·76	·093	20·32	·85	13·75
	40	7·41	·77		19·47	·86	13·76
	50	6·64	·78		18·61	·87	13·76
207	0	−26 5·86	·80	−·092	+5 17·74	·86	+13·77
	10	5·06	·81		16·88	·87	13·77
	20	4·25	·82		16·01	·87	13·78
	30	3·43	·84	·092	15·14	·87	13·78
	40	2·59	·85		14·27	·88	13·79
	50	1·74	·86		13·39	·88	13·79
208	0	−26 0·88	·87	−·091	+5 12·51	·88	+13·79
	10	26 0·01	·89		11·63	·89	13·79
	20	25 59·12	·90		10·74	·88	13·80
	30	25 58·22	·92	·090	9·86	·89	13·80
	40	25 57·30	·92		8·97	·89	13·80
	50	25 56·38	·94		8·08	·90	13·80
209	0	−25 55·44	·96	−·089	+5 7·18	·90	+13·80
	10	54·48	·96		6·28	·90	13·80
	20	53·52	·98		5·38	·90	13·80
	30	52·54	0·99	·088	4·48	·90	13·79
	40	51·55	1·01		3·58	·91	13·79
	50	50·54	1·02		2 67	0·91	13·79
210	0	−25 49·52		−·088ν	+5 1·76		+13·79

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
210°	0′	−25° 49′·52	1·03	−·088ν	+5° 1′·76	0·91	+13′·79
	10	48·49	1·04		5 0·85	·92	13·78
	20	47·45	1·06		4 59·93	·92	13·78
	30	46·39	1·07	·087	4 59·01	·92	13·78
	40	45·32	1·08		4 58·09	·92	13·77
	50	44·24	1·10		4 57·17	·93	13·77
211	0	−25 43·14	1·11	−·086	+4 56·24	·92	+13·76
	10	42·03	1·12		55·32	·93	13·75
	20	40·91	1·14		54·39	·94	13·75
	30	39·77	1·15	·085	53·45	·93	13·74
	40	38·62	1·16		52·52	·94	13·73
	50	37·46	1·18		51·58	·94	13·72
212	0	−25 36·28	1·18	−·084	+4 50·64	·94	+13·72
	10	35·10	1·20		49·70	·95	13·71
	20	33·90	1·22		48·75	·94	13·70
	30	32·68	1·23	·084	47·81	·95	13·69
	40	31·45	1·24		46·86	·95	13·68
	50	30·21	1·25		45·91	·96	13·67
213	0	−25 28·96	1·27	−·083	+4 44·95	·96	+13·66
	10	27·69	1·28		43·99	·96	13·64
	20	26·41	1·29		43·03	·96	13·63
	30	25·12	1·30	·082	42·07	·96	13·62
	40	23·82	1·32		41·11	·97	13·61
	50	22·50	1·34		40·14	·97	13·59
214	0	−25 21·16	1·34	−·081	+4 39·17	·97	+13·58
	10	19·82	1·36		38 20	·97	13·56
	20	18·46	1·37		37·23	·98	13·55
	30	17·09	1·38	·080	36·25	·97	13·53
	40	15·71	1·40		35·28	·98	13·52
	50	14·31	1·41		34·30	·99	13·50
215	0	−25 12·90	1·42	−·079	+4 33·31	·98	+13·49
	10	11·48	1·44		32·33	·99	13·47
	20	10·04	1·45		31·34	·99	13·45
	30	8·59	1·46	·078	30·35	·99	13·43
	40	7·13	1·48		29·36	0·99	13·41
	50	5·65	1·49		28·37	1·00	13·39
216	0	−25 4·16	1·50	−·078	+4 27·37	1·00	+13·37
	10	25 2·66	1·51		26·37	1·00	13·35
	20	25 1·15	1·53		25·37	1·00	13·33
	30	24 59·62	1·55	·077	24·37	1·01	13·31
	40	24 58·07	1·55		23·36	1·01	13·29
	50	24 56·52	1·57		22·35	1·01	13·27
217	0	−24 54·95	1·58	−·076	+4 21·34	1·01	+13·25
	10	53·37	1·59		20·33	1·01	13·23
	20	51·78	1·61		19·32	1·02	13·20
	30	50·17	1·62	·075	18·30	1·02	13·18
	40	48·55	1·63		17·28	1·02	13·16
	50	46·92	1·64		16·26	1·02	13·13
218	0	−24 45·28	1·66	−·074	+4 15·24	1·03	+13·11
	10	43·62	1·67		14·21	1·02	13·08
	20	41·95	1·69		13·19	1·03	13·06
	30	40·26	1·69	·073	12·16	1·03	13·03
	40	38·57	1·71		11·13	1·04	13·00
	50	36·86	1·73		10·09	1·03	12·97
219	0	−24 35·13	1·74	−·072	+4 9·06	1·04	+12·95
	10	33·39	1·75		8·02	1·04	12·92
	20	31·64	1·76		6·98	1·04	12·89
	30	29·88	1·78	·071	5·94	1·04	12·86
	40	28·10	1·79		4·90	1·05	12·83
	50	26·31	1·80		3·85	1·05	12·80
220	0	−24 24·51		−·070ν	+4 2·80		+12·77

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
220°	0′	−24° 24′·51	1·81	−·070	+4° 2′·80	1·05	+12′·77
	10	22·70	1·83		4 1·75	1·05	12·74
	20	20·87	1·84		4 0·70	1·05	12·71
	30	19·03	1·85	·069	3 59·65	1·06	12·68
	40	17·18	1·87		3 58·59	1·06	12·65
	50	15·31	1·88		3 57·53	1·06	12·62
221	0	−24 13·43	1·89	−·069	+3 56·47	1·06	+12·58
	10	11·54	1·91		55·41	1·06	12·55
	20	9·63	1·92		54·35	1·07	12·52
	30	7·71	1·93	·068	53·28	1·07	12·48
	40	5·78	1·94		52·21	1·07	12·45
	50	3·84	1·96		51·14	1·07	12·41
222	0	−24 1·88	1·97	−·067	+3 50·07	1·07	+12·38
	10	23 59·91	1·98		49·00	1·08	12·34
	20	57·93	2·00		47·92	1·07	12·31
	30	55·93	2·01	·066	46·85	1·08	12·27
	40	53·92	2·02		45·77	1·08	12·23
	50	51·90	2·03		44·69	1·09	12·20
223	0	−23 49·87	2·05	−·065	+3 43·60	1·08	+12·16
	10	47·82	2·06		42·52	1·09	12·12
	20	45·76	2·07		41·43	1·09	12·08
	30	43·69	2·09	·064	40·34	1·09	12·04
	40	41·60	2·10		39·25	1·09	12·00
	50	39·50	2·11		38·16	1·10	11·96
224	0	−23 37·39	2·13	−·063	+3 37·06	1·09	+11·92
	10	35·26	2·14		35·97	1·10	11·88
	20	33·12	2·15		34·87	1·10	11·84
	30	30·97	2·16	·062	33·77	1·10	11·80
	40	28·81	2·17		32·67	1·10	11·76
	50	26·64	2·19		31·57	1·11	11·72
225	0	−23 24·45	2·21	−·061	+3 30·46	1·11	+11·68
	10	22·24	2·21		29·35	1·10	11·63
	20	20·03	2·23		28·25	1·11	11·59
	30	17·80	2·24	·060	27·14	1·12	11·55
	40	15·56	2·25		26·02	1·11	11·50
	50	13·31	2·26		24·91	1·12	11·46
226	0	−23 11·05	2·28	−·059	+3 23·79	1·11	+11·41
	10	23 8·77	2·29		22·68	1·12	11·37
	20	23 6·48	2·31		21·56	1·12	11·32
	30	23 4·17	2·31	·058	20·44	1·12	11·28
	40	23 1·86	2·33		19·32	1·13	11·23
	50	22 59·53	2·34		18·19	1·12	11·18
227	0	−22 57·19	2·36	−·057	+3 17·07	1·13	+11·14
	10	54·83	2·36		15·94	1·13	11·09
	20	52·47	2·38		14·81	1·13	11·04
	30	50·09	2·40	·056	13·68	1·13	10·99
	40	47·69	2·40		12·55	1·14	10·94
	50	45·29	2·42		11·41	1·13	10·89
228	0	−22 42·87	2·43	−·055	+3 10·28	1·14	+10·85
	10	40·44	2·44		9·14	1·14	10·80
	20	38·00	2·46		8·00	1·14	10·75
	30	35·54	2·46	·054	6·86	1·14	10·70
	40	33·08	2·48		5·72	1·14	10·64
	50	30·60	2·50		4·58	1·14	10·59
229	0	−22 28·10	2·50	−·053	+3 3·44	1·15	+10·54
	10	25·60	2·52		3 2·29	1·15	10·49
	20	23·08	2·53		3 1·14	1·15	10·44
	30	20·55	2·54	·052	2 59·99	1·15	10·39
	40	18·01	2·56		2 58·84	1·15	10·33
	50	15·45	2·56		2 57·69	1·15	10·28
230	0	−22 12·89		−·051	+2 56·54		+10·23

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
230°	0′	−22° 12′·89	2·58	−·051	+2° 56′·54	1·16	+10′·23
	10	22 10·31	2·60		55·38	1·15	10·17
	20	22 7·71	2·60		54·23	1·16	10·12
	30	22 5·11	2·62	·050	53·07	1·16	10·06
	40	22 2·49	2·63		51·91	1·16	10·01
	50	21 59·86	2·64		50·75	1·17	9·95
231	0	−21 57·22	2·65	−·049	+2 49·58	1·16	+ 9·90
	10	54·57	2·67		48·42	1·16	9·84
	20	51·90	2·68		47·26	1·17	9·79
	30	49·22	2·69	·048	46·09	1·17	9·73
	40	46·53	2·70		44·92	1·17	9·67
	50	43·83	2·72		43·75	1·17	9·61
232	0	−21 41·11	2·73	−·047	+2 42·58	1·17	+ 9·56
	10	38·38	2·74		41·41	1·18	9·50
	20	35·64	2·75		40·23	1·17	9·44
	30	32·89	2·76	·046	39·06	1·17	9·38
	40	30·13	2·78		37·89	1·18	9·32
	50	27·35	2·79		36·71	1·18	9·26
233	0	−21 24·56	2·80	−·045	+2 35·53	1·18	+ 9·21
	10	21·76	2·81		34·35	1·18	9·15
	20	18·95	2·83		33·17	1·19	9·09
	30	16·12	2·84	·044	31·98	1·18	9·03
	40	13·28	2·85		30·80	1·19	8·96
	50	10·43	2·86		29·61	1·18	8·90
234	0	−21 7·57	2·87	−·043	+2 28·43	1·19	+ 8·84
	10	21 4·70	2·88		27·24	1·19	8·78
	20	21 1·82	2·90		26·05	1·19	8·72
	30	20 58·92	2·91	·042	24·86	1·19	8·66
	40	20 56·01	2·92		23·67	1·19	8·59
	50	20 53·09	2·94		22·48	1·20	8·53
235	0	−20 50·15	2·94	−·041	+2 21·28	1·19	+ 8·47
	10	47·21	2·96		20·09	1·19	8·40
	20	44·25	2·97		18·90	1·20	8·34
	30	41·28	2·98	·040	17·70	1·20	8·28
	40	38·30	2·99		16·50	1·20	8·21
	50	35·31	3·00		15·30	1·20	8·15
236	0	−20 32·31	3·02	−·039	+2 14·10	1·20	+ 8·08
	10	29·29	3·03		12·90	1·21	8·02
	20	26·26	3·04		11·69	1·20	7·95
	30	23·22	3·05	·038	10·49	1·20	7·89
	40	20·17	3·06		9·29	1·21	7·82
	50	17·11	3·07		8·08	1·21	7·76
237	0	−20 14·04	3·09	−·037	+2 6·87	1·21	+ 7·69
	10	20 10·95	3·10		5·66	1·21	7·63
	20	20 7·85	3·11		4·45	1·21	7·56
	30	20 4·74	3·12	·036	3·24	1·21	7·49
	40	20 1·62	3·13		2·03	1·21	7·42
	50	19 58·49	3·15		2 0·82	1·21	7·35
238	0	−19 55·34	3·15	−·035	+1 59·61	1·22	+ 7·29
	10	52·19	3·17		58·39	1·21	7·22
	20	49·02	3·18		57·18	1·22	7·15
	30	45·84	3·19	·033	55·96	1·22	7·08
	40	42·65	3·20		54·74	1·21	7·01
	50	39·45	3·21		53·53	1·22	6·94
239	0	−19 36·24	3·22	−·032	+1 52·31	1·22	+ 6·87
	10	33·02	3·24		51·09	1·23	6·81
	20	29·78	3·25		49·86	1·22	6·74
	30	26·53	3·25	·031	48·64	1·22	6·67
	40	23·28	3·27		47·42	1·22	6·60
	50	20·01	3·28		46·20	1·23	6·53
240	0	−19 16·73		−·030	+1 44·97		+ 6·45

☉	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
240° 0′	−19° 16′·73		−·030	+1° 44′·97		+6′·45
10	19 13·43	3·30		43·75	1·22	6·38
20	19 10·13	3·30		42·52	1·23	6·31
30	19 6·82	3·31	·029	41·29	1·23	6·24
40	19 3·49	3·33		40·06	1·23	6·17
50	19 0·16	3·33		38·84	1·22	6·10
241 0	−18 56·81	3·35	−·028	+1 37·61	1·23	+6·03
10	18 53·45	3·36		36·38	1·23	5·95
20	18 50·08	3·37		35·14	1·24	5·88
30	18 46·70	3·38	·027	33·91	1·23	5·81
40	18 43·31	3·39		32·68	1·23	5·74
50	18 39·91	3·40		31·45	1·23	5·66
242 0	−18 36·50	3·41	−·026	+1 30·21	1·24	+5·59
10	18 33·07	3·43		28·97	1·24	5·52
20	18 29·64	3·43		27·73	1·24	5·44
30	18 26·19	3·45	·025	26·50	1·23	5·37
40	18 22·74	3·45		25·27	1·23	5·30
50	18 19·27	3·47		24·03	1·24	5·22
243 0	−18 15·79	3·48	−·024	+1 22·79	1·24	+5·15
10	18 12·30	3·49		21·55	1·24	5·07
20	18 8·80	3·50		20·31	1·24	5·00
30	18 5·29	3·51	·023	19·07	1·24	4·93
40	18 1·77	3·52		17·83	1·24	4·85
50	17 58·24	3·53		16·58	1·25	4·78
244 0	−17 54·70	3·54	−·022	+1 15·34	1·24	+4·70
10	17 51·15	3·55		14·10	1·24	4·63
20	17 47·59	3·56		12·85	1·25	4·55
30	17 44·02	3·57	·021	11·61	1·24	4·47
40	17 40·43	3·59		10·37	1·24	4·40
50	17 36·84	3·59		9·12	1·25	4·32
245 0	−17 33·23	3·61	−·020	+1 7·87	1·25	+4·25
10	17 29·62	3·61		6·62	1·25	4·17
20	17 26·00	3·62		5·38	1·24	4·10
30	17 22·36	3·64	·019	4·13	1·25	4·02
40	17 18·72	3·64		2·88	1·25	3·94
50	17 15·06	3·66		1·63	1·25	3·87
246 0	−17 11·40	3·66	−·017	+1 0·38	1·25	+3·79
10	17 7·72	3·68		0 59·13	1·25	3·71
20	17 4·04	3·68		57·88	1·25	3·64
30	17 0·34	3·70	·016	56·63	1·25	3·56
40	16 56·63	3·71		55·38	1·25	3·48
50	16 52·92	3·71		54·13	1·25	3·40
247 0	−16 49·19	3·73	−·015	+0 52·87	1·26	+3·33
10	16 45·46	3·73		51·62	1·25	3·25
20	16 41·71	3·75		50·37	1·25	3·17
30	16 37·96	3·75	·014	49·11	1·26	3·09
40	16 34·19	3·77		47·86	1·25	3·01
50	16 30·42	3·77		46·61	1·25	2·94
248 0	−16 26·64	3·78	−·013	+0 45·35	1·26	+2·86
10	16 22·84	3·80		44·09	1·26	2·78
20	16 19·04	3·80		42·84	1·25	2·70
30	16 15·23	3·81	·012	41·58	1·26	2·62
40	16 11·40	3·83		40·33	1·25	2·54
50	16 7·57	3·83		39·07	1·26	2·46
249 0	−16 3·73	3·84	−·011	+0 37·81	1·26	+2·39
10	15 59·88	3·85		36·55	1·26	2·31
20	15 56·02	3·86		35·29	1·26	2·23
30	15 52·15	3·87	·010	34·04	1·25	2·15
40	15 48·27	3·88		32·78	1·26	2·07
50	15 44·38	3·89		31·52	1·26	1·99
250 0	−15 40·48	3·90	−·009	+0 30·26	1·26	+1·91

☉	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
250° 0′	−15° 40′·48		−·009	+0° 30′·26		+1′·91
10	15 36·57	3·91		29·01	1·25	1·83
20	15 32·66	3·91		27·75	1·26	1·75
30	15 28·73	3·93	·008	26·49	1·26	1·67
40	15 24·80	3·93		25·23	1·26	1·60
50	15 20·85	3·95		23·97	1·26	1·52
251 0	−15 16·90	3·95	−·007	+0 22·71	1·26	+1·44
10	15 12·94	3·96		21·45	1·26	1·36
20	15 8·97	3·97		20·19	1·26	1·28
30	15 4·99	3·98	·005	18·92	1·27	1·20
40	15 1·00	3·99		17·66	1·26	1·12
50	14 57·00	4·00		16·40	1·26	1·04
252 0	−14 53·00	4·00	−·004	+0 15·14	1·26	+0·96
10	14 48·98	4·02		13·88	1·26	0·88
20	14 44·96	4·02		12·62	1·26	0·80
30	14 40·93	4·03	·003	11·36	1·26	0·72
40	14 36·89	4·04		10·10	1·26	0·64
50	14 32·84	4·05		8·83	1·27	0·56
253 0	−14 28·78	4·06	−·002	+0 7·57	1·26	+0·48
10	14 24·71	4·07		6·31	1·26	0·40
20	14 20·63	4·08		5·05	1·26	0·32
30	14 16·55	4·08	−·001	3·79	1·26	0·24
40	14 12·46	4·09		2·52	1·27	0·16
50	14 8·36	4·10		+ 1·26	1·26	+0·08
254 0	−14 4·25	4·11	·000	0 0·00	1·26	0·00
10	14 0·13	4·12		− 1·26	1·26	−0·08
20	13 56·01	4·12		2·52	1·26	0·16
30	13 51·88	4·13	+·001	3·79	1·27	0·24
40	13 47·74	4·14		5·05	1·26	0·32
50	13 43·59	4·15		6·31	1·26	0·40
255 0	−13 39·43	4·16	+·002	−0 7·57	1·26	−0·48
10	13 35·26	4·17		8·83	1·26	0·56
20	13 31·09	4·17		10·10	1·27	0·64
30	13 26·91	4·18	·003	11·36	1·26	0·72
40	13 22·72	4·19		12·62	1·26	0·80
50	13 18·53	4·19		13·88	1·26	0·88
256 0	−13 14·32	4·21	+·004	−0 15·14	1·26	−0·96
10	13 10·11	4·21		16·40	1·26	1·04
20	13 5·89	4·22		17·66	1·26	1·12
30	13 1·66	4·23	·005	18·92	1·26	1·20
40	12 57·43	4·23		20·19	1·27	1·28
50	12 53·18	4·25		21·45	1·26	1·36
257 0	−12 48·93	4·25	+·007	−0 22·71	1·26	−1·44
10	12 44·67	4·26		23·97	1·26	1·52
20	12 40·41	4·26		25·23	1·26	1·60
30	12 36·14	4·27	·008	26·49	1·26	1·67
40	12 31·86	4·28		27·75	1·26	1·75
50	12 27·57	4·29		29·01	1·26	1·83
258 0	−12 23·28	4·29	+·009	−0 30·26	1·25	−1·91
10	12 18·98	4·30		31·52	1·26	1·99
20	12 14·67	4·31		32·78	1·26	2·07
30	12 10·35	4·32	·010	34·04	1·26	2·15
40	12 6·03	4·32		35·29	1·25	2·23
50	12 1·70	4·33		36·55	1·26	2·31
259 0	−11 57·36	4·34	+·011	−0 37·81	1·26	−2·39
10	11 53·02	4·34		39·07	1·26	2·46
20	11 48·67	4·35		40·33	1·26	2·54
30	11 44·31	4·36	·012	41·58	1·25	2·62
40	11 39·95	4·36		42·84	1·26	2·70
50	11 35·58	4·37		44·09	1·25	2·78
260 0	−11 31·20	4·38	+·013	−0 45·35	1·26	−2·86

☉		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
260°	0′	−11° 31′·20	4·38	+·013ν	−0° 45′·35	1·26	−2′·86
	10	11 26·82	4·39		46·61	1·25	2·94
	20	11 22·43	4·40		47·86	1·25	3·01
	30	11 18·03	4·40	·014	49·11	1·26	3·09
	40	11 13·63	4·41		50·37	1·25	3·17
	50	11 9·22	4·42		51·62	1·25	3·25
261	0	−11 4·80	4·42	+·015	−0 52·87	1·26	−3·33
	10	11 0·38	4·43		54·13	1·25	3·40
	20	10 55·95	4·43		55·38	1·25	3·48
	30	10 51·52	4·44	·016	56·63	1·25	3·56
	40	10 47·08	4·45		57·88	1·25	3·64
	50	10 42·63	4·45		0 59·13	1·25	3·71
262	0	−10 38·18	4·46	+·017	−1 0·38	1·25	−3·79
	10	10 33·72	4·47		1·63	1·25	3·87
	20	10 29·25	4·47		2·88	1·25	3·94
	30	10 24·78	4·48	·019	4·13	1·25	4·02
	40	10 20·30	4·48		5·38	1·24	4·10
	50	10 15·82	4·48		6·62	1·25	4·17
263	0	−10 11·34	4·50	+·020	−1 7·87	1·25	−4·25
	10	10 6·84	4·50		9·12	1·25	4·32
	20	10 2·34	4·50		10·37	1·24	4·40
	30	9 57·84	4·51	·021	11·61	1·24	4·47
	40	9 53·33	4·52		12·85	1·25	4·55
	50	9 48·81	4·52		14·10	1·24	4·63
264	0	−9 44·29	4·53	+·022	−1 15·34	1·24	−4·70
	10	9 39·76	4·53		16·58	1·25	4·78
	20	9 35·23	4·54		17·83	1·24	4·85
	30	9 30·69	4·54	·023	19·07	1·24	4·93
	40	9 26·15	4·55		20·31	1·24	5·00
	50	9 21·60	4·55		21·55	1·24	5·07
265	0	−9 17·05	4·56	+·024	−1 22·79	1·24	−5·15
	10	9 12·49	4·56		24·03	1·24	5·22
	20	9 7·93	4·57		25·27	1·23	5·30
	30	9 3·36	4·57	·025	26·50	1·23	5·37
	40	8 58·79	4·58		27·73	1·24	5·44
	50	8 54·21	4·59		28·97	1·24	5·52
266	0	−8 49·62	4·59	+·026	−1 30·21	1·24	−5·59
	10	8 45·03	4·59		31·45	1·23	5·66
	20	8 40·44	4·59		32·68	1·23	5·74
	30	8 35·85	4·60	·027	33·91	1·23	5·81
	40	8 31·25	4·61		35·14	1·24	5·88
	50	8 26·64	4·61		36·38	1·23	5·95
267	0	−8 22·03	4·62	+·028	−1 37·61	1·23	−6·03
	10	8 17·41	4·62		38·84	1·22	6·10
	20	8 12·79	4·62		40·06	1·23	6·17
	30	8 8·17	4·63	·029	41·29	1·23	6·24
	40	8 3·54	4·63		42·52	1·23	6·31
	50	7 58·91	4·64		43·75	1·22	6·38
268	0	−7 54·27	4·64	+·030	−1 44·97	1·23	−6·45
	10	7 49·63	4·65		46·20	1·22	6·53
	20	7 44·98	4·65		47·42	1·22	6·60
	30	7 40·33	4·65	·031	48·64	1·22	6·67
	40	7 35·68	4·66		49·86	1·23	6·74
	50	7 31·02	4·66		51·09	1·22	6·81
269	0	−7 26·36	4·66	+·032	−1 52·31	1·22	−6·87
	10	7 21·70	4·67		53·53	1·21	6·94
	20	7 17·03	4·67		54·74	1·22	7·01
	30	7 12·36	4·68	·033	55·96	1·22	7·08
	40	7 7·68	4·68		57·18	1·21	7·15
	50	7 3·00	4·68		58·39	1·22	7·22
270	0	−6 58·32		+·035ν	−1 59·61		−7·29

☉		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
270°	0′	−6° 58′·32	4·69	+·035ν	−1° 59′·61	1·21	−7′·29
	10	6 53·63	4·69		2 0·82	1·21	7·35
	20	6 48·94	4·69		2·03	1·21	7·42
	30	6 44·25	4·70	·036	3·24	1·21	7·49
	40	6 39·55	4·70		4·45	1·21	7·56
	50	6 34·85	4·70		5·66	1·21	7·63
271	0	−6 30·15	4·71	+·037	−2 6·87	1·21	−7·69
	10	6 25·44	4·71		8·08	1·21	7·76
	20	6 20·73	4·71		9·29	1·20	7·82
	30	6 16·02	4·72	·038	10·49	1·20	7·89
	40	6 11·30	4·72		11·69	1·21	7·95
	50	6 6·58	4·72		12·90	1·20	8·02
272	0	−6 1·86	4·72	+·039	−2 14·10	1·20	−8·08
	10	5 57·14	4·73		15·30	1·20	8·15
	20	5 52·41	4·73		16·50	1·20	8·21
	30	5 47·68	4·73	·040	17·70	1·20	8·28
	40	5 42·95	4·74		18·90	1·19	8·34
	50	5 38·21	4·74		20·09	1·19	8·40
273	0	−5 33·47	4·74	+·041	−2 21·28	1·20	−8·47
	10	5 28·73	4·74		22·48	1·19	8·53
	20	5 23·99	4·75		23·67	1·19	8·59
	30	5 19·24	4·75	·042	24·86	1·19	8·66
	40	5 14·49	4·75		26·05	1·19	8·72
	50	5 9·74	4·75		27·24	1·19	8·78
274	0	−5 4·99	4·75	+·043	−2 28·43	1·18	−8·84
	10	5 0·24	4·76		29·61	1·19	8·90
	20	4 55·48	4·76		30·80	1·18	8·96
	30	4 50·72	4·76	·044	31·98	1·19	9·03
	40	4 45·96	4·77		33·17	1·18	9·09
	50	4 41·19	4·76		34·35	1·18	9·15
275	0	−4 36·43	4·77	+·045	−2 35·53	1·18	−9·21
	10	4 31·66	4·77		36·71	1·18	9·26
	20	4 26·89	4·77		37·89	1·17	9·32
	30	4 22·12	4·77	·046	39·06	1·17	9·38
	40	4 17·35	4·77		40·23	1·18	9·44
	50	4 12·58	4·78		41·41	1·17	9·50
276	0	−4 7·80	4·78	+·047	−2 42·58	1·17	−9·56
	10	4 3·02	4·78		43·75	1·17	9·61
	20	3 58·24	4·78		44·92	1·17	9·67
	30	3 53·46	4·78	·048	46·09	1·17	9·73
	40	3 48·68	4·79		47·26	1·16	9·79
	50	3 43·89	4·78		48·42	1·16	9·84
277	0	−3 39·11	4·79	+·049	−2 49·58	1·17	−9·90
	10	3 34·32	4·78		50·75	1·16	9·95
	20	3 29·54	4·79		51·91	1·16	10·01
	30	3 24·75	4·79	·050	53·07	1·16	10·06
	40	3 19·96	4·79		54·23	1·15	10·12
	50	3 15·17	4·79		55·38	1·16	10·17
278	0	−3 10·38	4·80	+·051	−2 56·54	1·15	−10·23
	10	3 5·58	4·79		2 57·69	1·15	10·28
	20	3 0·79	4·79		2 58·84	1·15	10·33
	30	2 56·00	4·80	·052	2 59·99	1·15	10·39
	40	2 51·20	4·80		3 1·14	1·15	10·44
	50	2 46·40	4·79		3 2·29	1·15	10·49
279	0	−2 41·61	4·80	+·053	−3 3·44	1·14	−10·54
	10	2 36·81	4·80		4·58	1·14	10·59
	20	2 32·01	4·80		5·72	1·14	10·64
	30	2 27·21	4·80	·054	6·86	1·14	10·70
	40	2 22·41	4·79		8·00	1·14	10·75
	50	2 17·62	4·80		9·14	1·14	10·80
280	0	−2 12·82		+·055ν	−3 10·28		−10·85

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
280°	0′	−2° 12′·82	4·80	+·055ν	−3° 10′·28	1·13	−10′·85
	10	2 8·02	4·80		11·41	1·14	10·89
	20	2 3·22	4·81		12·55	1·13	10·94
	30	1 58·41	4·80	·056	13·68	1·13	10·99
	40	1 53·61	4·80		14·81	1·13	11·04
	50	1 48·81	4·80		15·94	1·13	11·09
281	0	−1 44·01	4·80	+·057	−3 17·07	1·12	−11·14
	10	1 39·21	4·80		18·19	1·13	11·18
	20	1 34·41	4·80		19·32	1·12	11·23
	30	1 29·61	4·80	·058	20·44	1·12	11·28
	40	1 24·81	4·80		21·56	1·12	11·32
	50	1 20·01	4·80		22·68	1·11	11·37
282	0	−1 15·21	4·80	+·059	−3 23·79	1·12	−11·41
	10	1 10·41	4·80		24·91	1·11	11·46
	20	1 5·61	4·80		26·02	1·12	11·50
	30	1 0·81	4·80	·060	27·14	1·11	11·55
	40	0 56·01	4·80		28·25	1·10	11·59
	50	0 51·21	4·80		29·35	1·11	11·63
283	0	−0 46·41	4·79	+·061	−3 30·46	1·11	−11·68
	10	0 41·62	4·80		31·57	1·10	11·72
	20	0 37·82	4·80		32·67	1·10	11·76
	30	0 32·02	4·79	·062	33·77	1·10	11·80
	40	0 27·23	4·80		34·87	1·10	11·84
	50	0 22·43	4·79		35·97	1·09	11·88
284	0	−0 17·64	4·79	+·063	−3 37·06	1·10	−11·92
	10	0 12·85	4·79		38·16	1·09	11·96
	20	0 8·06	4·79		39·25	1·09	12·00
	30	−0 3·27	4·79	·064	40·34	1·09	12·04
	40	+0 1·52	4·79		41·43	1·09	12·08
	50	0 6·31	4·79		42·52	1·08	12·12
285	0	+0 11·10	4·79	+·065	−3 43·60	1·09	−12·16
	10	0 15·89	4·78		44·69	1·08	12·20
	20	0 20·67	4·79		45·77	1·08	12·23
	30	0 25·46	4·78	·066	46·85	1·07	12·27
	40	0 30·24	4·78		47·92	1·08	12·31
	50	0 35·02	4·78		49·00	1·07	12·34
286	0	+0 39·80	4·78	+·067	−3 50·07	1·07	−12·38
	10	0 44·58	4·77		51·14	1·07	12·41
	20	0 49·35	4·78		52·21	1·07	12·45
	30	0 54·13	4·77	·068	53·28	1·07	12·48
	40	0 58·90	4·77		54·35	1·06	12·52
	50	1 3·67	4·77		55·41	1·06	12·55
287	0	+1 8·44	4·77	+·069	−3 56·47	1·06	−12·58
	10	1 13·21	4·77		3 57·53	1·06	12·62
	20	1 17·98	4·76		3 58·59	1·06	12·65
	30	1 22·74	4·77	·069	3 59·65	1·05	12·68
	40	1 27·51	4·76		4 0·70	1·05	12·71
	50	1 32·27	4·76		4 1·75	1·05	12·74
288	0	+1 37·03	4·75	+·070	−4 2·80	1·05	−12·77
	10	1 41·78	4·76		3·85	1·05	12·80
	20	1 46·54	4·75		4·90	1·04	12·83
	30	1 51·29	4·75	·071	5·94	1·04	12·86
	40	1 56·04	4·75		6·98	1·04	12·89
	50	2 0·79	4·74		8·02	1·04	12·92
289	0	+2 5·53	4·75	+·072	−4 9·06	1·03	−12·95
	10	2 10·28	4·74		10·09	1·04	12·97
	20	2 15·02	4·74		11·13	1·03	13·00
	30	2 19·76	4·73	·073	12·16	1·03	13 03
	40	2 24·49	4·74		13·19	1·02	13·06
	50	2 29·23	4·73		14·21	1·03	13·08
290	0	+2 33·96		+·074ν	−4 15·24		−13·11

⊙		Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
290°	0′	+2° 33′·96	4·73	+·074ν	−4° 15′·24	1·02	−13′·11
	10	2 38·69	4·72		16·26	1·02	13·13
	20	2 43·41	4·73		17·28	1·02	13·16
	30	2 48·14	4·72	·075	18·30	1·02	13·18
	40	2 52·86	4·71		19·32	1·01	13·20
	50	2 57·57	4·72		20·33	1·01	13·23
291	0	+3 2·29	4·71	+·076	−4 21·34	1·01	−13·25
	10	3 7·00	4·71		22·35	1·01	13·27
	20	3 11·71	4·71		23·36	1·01	13·29
	30	3 16·42	4·70	·077	24·37	1·00	13·31
	40	3 21·12	4·70		25·37	1·00	13·33
	50	3 25·82	4·70		26·37	1·00	13·35
292	0	+3 30 52	4·69	+·078	−4 27·37	1 00	−13·37
	10	3 35·21	4·69		28·37	0·99	13·39
	20	3 39·90	4·69		29·36	·99	13·41
	30	3 44·59	4·68	·078	30 35	·99	13·43
	40	3 49·27	4·68		31·34	·99	13·45
	50	3 53·95	4·68		32·33	·98	13·47
293	0	+3 58·63	4·67	+·079	−4 33·31	·99	−13·49
	10	4 3·30	4·67		34·30	·98	13·50
	20	4 7·97	4·67		35·28	·97	13·52
	30	4 12·64	4·67	·080	36·25	·98	13·53
	40	4 17·31	4·66		37·23	·97	13·55
	50	4 21·97	4·65		38·20	·97	13·56
294	0	+4 26·62	4·65	+·081	−4 39·17	·97	−13·58
	10	4 31·27	4 65		40·14	·97	13·59
	20	4 35·92	4·65		41·11	·96	13·61
	30	4 40·57	4·64	·082	42·07	·96	13·62
	40	4 45·21	4·64		43·03	·96	13·63
	50	4 49·85	4·63		43·99	·96	13·64
295	0	+4 54·48	4·63	+·083	−4 44·95	·96	−13·66
	10	4 59·11	4·63		45·91	·95	13·67
	20	5 3·74	4·62		46·86	·95	13·68
	30	5 8·36	4·62	·084	47·81	·94	13·69
	40	5 12·98	4·61		48·75	·95	13·70
	50	5 17·59	4·61		49·70	·94	13·71
296	0	+5 22·20	4·61	+·084	−4 50·64	·94	−13·72
	10	5 26·81	4·60		51·58	·94	13·72
	20	5 31·41	4·60		52·52	·93	13·73
	30	5 36·01	4·59	·085	53·45	·94	13·74
	40	5 40·60	4·59		54·39	·93	13·75
	50	5 45·19	4·58		55·32	·92	13·75
297	0	+5 49·77	4·58	+·086	−4 56·24	·93	−13·76
	10	5 54·35	4·58		4 57·17	·92	13·77
	20	5 58·93	4·57		4 58·09	·92	13·77
	30	6 3·50	4·57	·087	4 59·01	·92	13·78
	40	6 8·07	4·56		4 59·93	·92	13·78
	50	6 12·63	4·55		5 0·85	·91	13·78
298	0	+6 17·18	4·56	+·088	−5 1·76	·91	−13·79
	10	6 21·74	4·55		2·67	·91	13·79
	20	6 26·29	4·54		3·58	·90	13·79
	30	6 30·83	4·54	·088	4·48	·90	13·79
	40	6 35·37	4·53		5·38	·90	13·80
	50	6 39·90	4·53		6·28	·90	13·80
299	0	+6 44·43	4·53	+·089	−5 7·18	·90	−13·80
	10	6 48·96	4·52		8·08	·89	13·80
	20	6 53·48	4·51		8·97	·89	13·80
	30	6 57·99	4·51	·090	9·86	·88	13·80
	40	7 2·50	4·50		10·74	·89	13·80
	50	7 7·00	4·50		11·63	0·88	13·79
300	0	+7 11·50		+ 091ν	−5 12·51		−13·79

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
300° 0′	+ 7° 11′·50	4·50	+·091ν	−5° 12′·51	0·88	−13′·79
10	7 16·00	4·49		13·39	·88	13·79
20	7 20·49	4·48		14·27	·87	13·79
30	7 24·97	4·48	·092	15·14	·87	13·78
40	7 29·45	4·47		16·01	·87	13·78
50	7 33·92	4·47		16·88	·86	13·77
301 0	+ 7 38·39	4·47	+·092	−5 17·74	·87	−13·77
10	7 42·86	4·46		18·61	·86	13·76
20	7 47·32	4·45		19·47	·85	13·76
30	7 51·77	4·45	·093	20·32	·86	13·75
40	7 56·22	4·44		21·18	·85	13·74
50	8 0·66	4·44		22·03	·85	13·74
302 0	+ 8 5·10	4·43	+·094	−5 22·88	·85	−13·73
10	8 9·53	4·42		23·73	·84	13·72
20	8 13·95	4·42		24·57	·84	13·71
30	8 18·37	4·42	·095	25·41	·84	13·70
40	8 22·79	4·41		26·25	·84	13·69
50	8 27·20	4·40		27·09	·83	13·68
303 0	+ 8 31·60	4·40	+·095	−5 27·92	·83	−13·67
10	8 36·00	4·39		28·75	·83	13·66
20	8 40·39	4·38		29·58	·82	13·65
30	8 44·77	4·38	·096	30·40	·83	13·64
40	8 49·15	4·38		31·23	·82	13·62
50	8 53·53	4·37		32·05	·81	13·61
304 0	+ 8 57·90	4·36	+·097	−5 32·86	·81	−13·60
10	9 2·26	4·36		33·67	·81	13·58
20	9 6·62	4·35		34·48	·81	13·57
30	9 10·97	4·34	·098	35·29	·81	13·55
40	9 15·31	4·34		36·10	·80	13·54
50	9 19·65	4·33		36·90	·80	13·52
305 0	+ 9 23·98	4·33	+·098	−5 37·70	·80	−13·51
10	9 28·31	4·32		38·50	·79	13·49
20	9 32·63	4·31		39·29	·79	13·47
30	9 36·94	4·31	·099	40·08	·79	13·46
40	9 41·25	4·30		40·87	·78	13·44
50	9 45·55	4·30		41·65	·77	13·42
306 0	+ 9 49·85	4·29	+·100	−5 42·44	·78	−13·40
10	9 54·14	4·28		43·22	·77	13·38
20	9 58·42	4·28		43·99	·78	13·36
30	10 2·70	4·27	·100	44·77	·77	13·34
40	10 6·97	4·26		45·54	·77	13·32
50	10 11·23	4·26		46·31	·76	13·30
307 0	+10 15·49	4·25	+·101	−5 47·07	·76	−13·28
10	10 19·74	4·25		47·83	·76	13·26
20	10 23·99	4·24		48·59	·76	13·23
30	10 28·23	4·23	·102	49·35	·75	13·21
40	10 32·46	4·22		50·10	·75	13·19
50	10 36·68	4·22		50·85	·75	13·16
308 0	+10 40·90	4·21	+·102	−5 51·60	·74	−13·14
10	10 45·11	4·21		52·34	·74	13·11
20	10 49·32	4·20		53·08	·74	13·09
30	10 53·52	4·19	·103	53·82	·73	13·06
40	10 57·71	4·18		54·55	·74	13·04
50	11 1·89	4·18		55·29	·73	13·01
309 0	+11 6·07	4·17	+·104	−5 56·02	·72	−12·98
10	11 10·24	4·17		56·74	·73	12·96
20	11 14·41	4·16		57·47	·72	12·93
30	11 18·57	4·15	·104	58·19	·71	12·90
40	11 22·72	4·14		58·90	·72	12·87
50	11 26·86	4·14		5 59·62	0·71	12·84
310 0	+11 31·00		+·105ν	−6 0·33		−12·81

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
310° 0′	+11° 31′·00	4·13	+·105ν	−6° 0′·33	0·71	−12′·81
10	11 35·13	4·12		1·04	·70	12·78
20	11 39·25	4·12		1·74	·70	12·75
30	11 43·37	4·11	·106	2·44	·70	12·72
40	11 47·48	4·10		3·14	·70	12·69
50	11 51·58	4·09		3·84	·69	12·66
311 0	+11 55·67	4·09	+·106	−6 4·53	·69	−12·63
10	11 59·76	4·08		5·22	·69	12·59
20	12 3·84	4·08		5·91	·68	12·56
30	12 7·92	4·06	·107	6·59	·68	12·53
40	12 11·98	4·06		7·27	·68	12·49
50	12 16·04	4·05		7·95	·67	12·46
312 0	+12 20·09	4·05	+·107	−6 8·62	·67	−12·42
10	12 24·14	4·03		9·29	·67	12·39
20	12 28·17	4·03		9·96	·67	12·35
30	12 32·20	4·03	·108	10·63	·66	12·32
40	12 36·23	4·01		11·29	·66	12·28
50	12 40·24	4·01		11·95	·65	12·24
313 0	+12 44·25	4·00	+·109	−6 12·60	·65	−12·21
10	12 48·25	3·99		13·25	·65	12·17
20	12 52·24	3·99		13·90	·65	12·13
30	12 56·23	3·98	·109	14·55	·64	12·09
40	13 0·21	3·97		15·19	·64	12·05
50	13 4·18	3·96		15·83	·64	12·01
314 0	+13 8·14	3·95	+·110	−6 16·47	·63	−11·97
10	13 12·09	3·95		17·10	·63	11·93
20	13 16·04	3·94		17·73	·63	11·89
30	13 19·98	3·93	·110	18·36	·62	11·85
40	13 23·91	3·93		18·98	·62	11·81
50	13 27·84	3·91		19·60	·62	11·77
315 0	+13 31·75	3·91	+·111	−6 20·22	·61	−11·73
10	13 35·66	3·90		20·83	·61	11·68
20	13 39·56	3·90		21·44	·61	11·64
30	13 43·46	3·88	·111	22·05	·61	11·60
40	13 47·34	3·88		22·66	·60	11·55
50	13 51·22	3·87		23·26	·60	11·51
316 0	+13 55·09	3·86	+·112	−6 23·86	·59	−11·46
10	13 58·95	3·86		24·45	·59	11·42
20	14 2·81	3·84		25·04	·59	11·37
30	14 6·65	3·84	·112	25·63	·58	11·33
40	14 10·49	3·83		26·21	·58	11·28
50	14 14·32	3·82		26·79	·58	11·24
317 0	+14 18·14	3·82	+·113	−6 27·37	·58	−11·19
10	14 21·96	3·81		27·95	·57	11·14
20	14 25·77	3·79		28·52	·57	11·09
30	14 29·56	3·79	·113	29·09	·56	11·05
40	14 33·35	3·79		29·65	·56	11·00
50	14 37·14	3·77		30·21	·56	10·95
318 0	+14 40·91	3·77	+·114	−6 30·77	·56	−10·90
10	14 44·68	3·75		31·33	·55	10·85
20	14 48·43	3·75		31·88	·55	10·80
30	14 52·18	3·75	·114	32·43	·55	10·75
40	14 55·93	3·73		32·98	·54	10·70
50	14 59·66	3·72		33·52	·54	10·65
319 0	+15 3·38	3·72	+·115	−6 34·06	·53	−10·60
10	15 7·10	3·71		34·59	·53	10·55
20	15 10·81	3·70		35·12	·53	10·49
30	15 14·51	3·69	·116	35·65	·53	10·44
40	15 18·20	3·68		36·18	·52	10·39
50	15 21·88	3·68		36·70	0·52	10·34
320 0	+15 25·56		+·116ν	−6 37·22		−10·28

⊙		Angle between the circle of declination and the sun's axis.				Heliographical latitude of the earth.			Reduction of longitude.
320°	0′	+15°	25′·56	3·67	+·116	−6°	37′·22	0·51	−10′·28
	10	15	29·23	3·66			37·73	·51	10·23
	20	15	32·89	3·64			38·24	·51	10·17
	30	15	36·53	3·64	·117		38·75	·51	10·12
	40	15	40·17	3·64			39·26	·50	10·06
	50	15	43·81	3·62			39·76	·50	10·01
321	0	+15	47·43	3·62	+·117	−6	40·26	·49	− 9·95
	10	15	51·05	3·60			40·75	·49	9·90
	20	15	54·65	3·60			41·24	·49	9·84
	30	15	58·25	3·59	·118		41·73	·48	9·78
	40	16	1·84	3·59			42·21	·48	9·73
	50	16	5·43	3·57			42·69	·48	9·67
322	0	+16	9·00	3·56	+·118	−6	43·17	·48	− 9·61
	10		12·56	3·56			43·65	·47	9·55
	20		16·12	3·55			44·12	·47	9·50
	30		19·67	3·54	·118		44·59	·46	9·44
	40		23·21	3·53			45·05	·46	9·38
	50		26·84	3·52			45·51	·46	9·32
323	0	+16	30·26	3·51	+·119	−6	45·97	·45	− 9·26
	10		33·77	3·50			46·42	·45	9·20
	20		37·27	3·50			46·87	·45	9·14
	30		40·77	3·48	·119		47·32	·44	9·08
	40		44·25	3·48			47·56	·44	9·02
	50		47·73	3·47			48·20	·44	8·96
324	0	+16	51·20	3·46	+·119	−6	48·64	·43	− 8·90
	10	16	54·66	3·45			49·07	·43	8·83
	20	16	58·11	3·44			49·50	·43	8·77
	30	17	1·55	3·43	·119		49·93	·42	8·71
	40	17	4·98	3·43			50·35	·42	8·65
	50	17	8·41	3·41			50·77	·41	8·58
325	0	+17	11·82	3·41	+·120	−6	51·18	·42	− 8·52
	10		15·23	3·40			51·60	·41	8·46
	20		18·63	3·38			52·01	·40	8·39
	30		22·01	3·38	·120		52·41	·40	8·33
	40		25·39	3·37			52·81	·40	8·27
	50		28·76	3·36			53·21	·39	8·21
326	0	+17	32·12	3·36	+·120	−6	53·60	·39	− 8·14
	10		35·48	3·34			53·99	·39	8·07
	20		38·82	3·33			54·38	·39	8·01
	30		42·15	3·33	·121		54·77	·38	7·94
	40		45·48	3·31			55·15	·37	7·87
	50		48·79	3·31			55·52	·38	7·81
327	0	+17	52·10	3·30	+·121	−6	55·90	·37	− 7·74
	10	17	55·40	3·29			56·27	·36	7·67
	20	17	58·69	3·27			56·63	·37	7·61
	30	18	1·96	3·27	·122		57·00	·36	7·54
	40	18	5·23	3·26			57·36	·35	7·47
	50	18	8·49	3·26			57·71	·35	7·40
328	0	+18	11·75	3·24	+·122	−6	58·06	·35	− 7·34
	10		14·99	3·23			58·41	·35	7·27
	20		18·22	3·22			58·76	·34	7·20
	30		21·44	3·22	·122		59·10	·34	7·13
	40		24·66	3·20			59·44	·33	7·06
	50		27·86	3·20		6	59·77	·33	6·99
329	0	+18	31·06	3·18	+·123	−7	0·10	·33	− 6·92
	10		34·24	3·18			0·43	·32	6·85
	20		37·42	3·17			0·75	·32	6·78
	30		40·59	3·16	·123		1·07	·32	6·71
	40		43·75	3·15			1·39	·31	6·64
	50		46·90	3·14			1·70	0·31	6·57
330	0	+18	50·04		+·123	−7	2·01		− 6·50

⊙		Angle between the circle of declination and the sun's axis.				Heliographical latitude of the earth.			Reduction of longitude.
330°	0′	+18°	50′·04	3·13	+·123	−7°	2′·01	0·31	− 6′·50
	10	18	53·17	3·12			2·32	·30	6·43
	20	18	56·29	3·11			2·62	·30	6·36
	30	18	59·40	3·10	·124		2·92	·29	6·29
	40	19	2·50	3·09			3·21	·29	6·21
	50	19	5·59	3·08			3·50	·29	6·14
331	0	+19	8·67	3·07	+·124	−7	3·79	·29	− 6·07
	10		11·74	3·07			4·08	·28	6·00
	20		14·81	3·05			4·36	·27	5·93
	30		17·86	3·04	·124		4·63	·28	5·85
	40		20·90	3·04			4·91	·27	5·78
	50		23·94	3·02			5·18	·26	5·71
332	0	+19	26·96	3·02	+·124	−7	5·44	·27	− 5·63
	10		29·98	3·00			5·71	·26	5·56
	20		32·98	3·00			5·97	·25	5·48
	30		35·98	2·99	·125		6·22	·25	5·41
	40		38·97	2·97			6·47	·25	5·34
	50		41·94	2·97			6·72	·25	5·26
333	0	+19	44·91	2·96	+·125	−7	6·97	·24	− 5·19
	10	19	47·87	2·94			7·21	·23	5·11
	20	19	50·81	2·94			7·44	·24	5·04
	30	19	53·75	2·93	·125		7·68	·23	4·96
	40	19	56·68	2·92			7·91	·22	4·89
	50	19	59·60	2·91			8·13	·23	4·81
334	0	+20	2·51	2·89	+·125	−7	8·36	·22	− 4·74
	10		5·40	2·89			8·58	·21	4·66
	20		8·29	2·88			8·79	·21	4·59
	30		11·17	2·87	·125		9·00	·21	4·51
	40		14·04	2·86			9·21	·21	4·43
	50		16·90	2·85			9·42	·20	4·36
335	0	+20	19·75	2·84	+·126	−7	9·62	·19	− 4·28
	10		22·59	2·83			9·81	·20	4·20
	20		25·42	2·82			10·01	·19	4·13
	30		28·24	2·81	·126		10·20	·18	4·05
	40		31·05	2·80			10·38	·18	3·97
	50		33·85	2·79			10·56	·18	3·90
336	0	+20	36·64	2·78	+·126	−7	10·74	·18	− 3·82
	10		39·42	2·77			10·92	·17	3·74
	20		42·19	2·76			11·09	·17	3·66
	30		44·95	2·75	·126		11·26	·16	3·59
	40		47·70	2·74			11·42	·16	3·51
	50		50·44	2·72			11·58	·16	3·43
337	0	+20	53·16	2·72	+·126	−7	11·74	·15	− 3·35
	10	20	55·88	2·71			11·89	·15	3·27
	20	20	58·59	2·70			12·04	·15	3·19
	30	21	1·29	2·69	·126		12·19	·14	3·12
	40	21	3·98	2·68			12·33	·14	3·04
	50	21	6·66	2·67			12·47	·13	2·96
338	0	+21	9·33	2·66	+·126	−7	12·60	·13	− 2·88
	10		11·99	2·65			12·73	·13	2·80
	20		14·64	2·64			12·86	·13	2·72
	30		17·28	2·62	·127		12·99	·12	2·64
	40		19·90	2·62			13·11	·11	2·56
	50		22·52	2·61			13·22	·12	2·48
339	0	+21	25·13	2·60	+·127	−7	13·34	·11	− 2·41
	10		27·73	2·59			13·45	·10	2·33
	20		30·32	2·58			13·55	·10	2·25
	30		32·90	2·56	·127		13·65	·10	2·17
	40		35·46	2·56			13·75	·09	2·09
	50		38·02	2·55			13·84	0·09	2·01
340	0	+21	40·57		+·127	−7	13·93		− 1·93

⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.	⊙	Angle between the circle of declination and the sun's axis.			Heliographical latitude of the earth.		Reduction of longitude.
340° 0'	+21° 40'·57	2·53	+·127	−7° 13'·93	0·09	−1'·93	350° 0'	+23° 54'·09	1·90	+·126	−7° 12'·60	0·13	+2'·88
10	43·10	2·53		14·02	·08	1·85	10	23 55·99	1·89		12·47	·14	2·96
20	45·63	2·51		14·10	·08	1·77	20	23 57·88	1·87		12·33	·14	3·04
30	48·14	2·51		14·18	·08	1·69	30	23 59·75	1·86	·126	12·19	·15	3·12
40	50·65	2·49		14·26	·07	1·61	40	24 1·61	1·86		12·04	·15	3·19
50	53·14	2·49		14·33	·07	1·53	50	24 3·47	1·84		11·89	·15	3·27
341 0	+21 55·63	2·47	+·127	−7 14·40	·07	−1·45	351 0	+24 5·31	1·83	+·126	−7 11·74	·16	+3·35
10	21 58·10	2·47		14·47	·06	1·37	10	7·14	1·82		11·58	·16	3·43
20	22 0·57	2·45		14·53	·05	1·29	20	8·96	1·81		11·42	·16	3·51
30	22 3·02	2·45		14·58	·06	1·21	30	10·77	1·79	·126	11·26	·17	3·59
40	22 5·47	2·43		14·64	·05	1·13	40	12·56	1·79		11·09	·17	3·66
50	22 7·90	2·42		14·69	·04	1·05	50	14·35	1·77		10·92	·18	3·74
342 0	+22 10·32	2·41	+·127	−7 14·73	·05	−0·97	352 0	+24 16·12	1·77	+·126	−7 10·74	·18	+3·82
10	12·73	2·40		14·78	·04	·89	10	17·89	1·75		10·56	·18	3·90
20	15·13	2·39		14·82	·03	·81	20	19·64	1·74		10·38	·18	3·97
30	17·52	2·39		14·85	·03	·73	30	21·38	1·73	·126	10·20	·19	4·05
40	19·91	2·37		14·88	·03	·64	40	23·11	1·72		10·01	·20	4·13
50	22·28	2·35		14·91	·02	·56	50	24·83	1·71		9·81	·19	4·20
343 0	+22 24·63	2·35	+·127	−7 14·93		−0·48	353 0	+24 26·54	1·69	+·126	−7 9·62	·20	+4·28
10	26·98	2·34		14·95		·40	10	28·23	1·69		9·42	·21	4·36
20	29·32	2·33		14·97		·32	20	29·92	1·67		9·21	·21	4·43
30	31·65	2·32		14·98		·24	30	31·59	1·66	·125	9·00	·21	4·51
40	33·97	2·31		14·99		·16	40	33·25	1·66		8·79	·21	4·59
50	36·28	2·29		15·00		— ·08	50	34·91	1·64		8·58	·22	4·66
344 0	+22 38·57	2·29	+·127	−7 15·00		·00	354 0	+24 36·55	1·63	+·125	−7 8·36	·23	+4·74
10	40·86	2·27		15·00		+ ·08	10	38·18	1·61		8·13	·22	4·81
20	43·13	2·27		14·99		·16	20	39·79	1·61		7·91	·23	4·89
30	45·40	2·25		14·98		·24	30	41·40	1·59	·125	7·68	·24	4·96
40	47·65	2·24		14·97		·32	40	42·99	1·59		7·44	·23	5·04
50	49·89	2·24		14·95		·40	50	44·58	1·57		7·21	·24	5·11
345 0	+22 52·13	2·22	+·127	−7 14·93	·02	+0·48	355 0	+24 46·15	1·56	+·125	−7 6·97	·25	+5·19
10	22 54·35	2·21		14·91	·03	·56	10	47·71	1·55		6·72	·25	5·26
20	22 56·56	2·20		14·88	·03	·64	20	49·26	1·54		6·47	·25	5·34
30	22 58·76	2·19		14·85	·03	·73	30	50·80	1·53	·125	6·22	·25	5·41
40	23 0·95	2·18		14·82	·04	·81	40	52·33	1·51		5·97	·26	5·48
50	23 3·13	2·17		14·78	·05	·89	50	53·84	1·51		5·71	·27	5·56
346 0	+23 5·30	2·15	+·127	−7 14·73	·04	+0·97	356 0	+24 55·35	1·49	+·124	−7 5·44	·26	+5·63
10	7·45	2·15		14·69	·05	1·05	10	24 56·84	1·48		5·18	·27	5·71
20	9·60	2·14		14·64	·06	1·13	20	24 58·32	1·47		4·91	·28	5·78
30	11·74	2·12		14·58	·05	1·21	30	24 59·79	1·46	·124	4·63	·27	5·85
40	13·86	2·12		14·53	·06	1·29	40	25 1·25	1·45		4·36	·28	5·93
50	15·98	2·10		14·47	·07	1·37	50	25 2·70	1·43		4·08	·29	6·00
347 0	+23 18·08	2·09	+·127	−7 14·40	·07	+1·45	357 0	+25 4·13	1·43	+·124	−7 3·79	·29	+6·07
10	20·17	2·09		14·33	·07	1·53	10	5·56	1·41		3·50	·29	6·14
20	22·26	2·07		14·26	·08	1·61	20	6·97	1·40		3·21	·29	6·21
30	24·33	2·06		14·18	·08	1·69	30	8·37	1·39	·124	2·92	·30	6·29
40	26·39	2·05		14·10	·08	1·77	40	9·76	1·38		2·62	·30	6·36
50	28·44	2·04		14·02	·09	1·85	50	11·14	1·36		2·32	·31	6·43
348 0	+23 30·48	2·03	+·127	−7 13·93	·09	+1·93	358 0	+25 12·50	1·36	+·123	−7 2·01	·31	+6·50
10	32·51	2·01		13·84	·09	2·01	10	13·86	1·34		1·70	·31	6·57
20	34·52	2·01		13·75	·10	2·09	20	15·20	1·33		1·39	·32	6·64
30	36·53	2·00		13·65	·10	2·17	30	16·53	1·32	·123	1·07	·32	6·71
40	38·53	1·98		13·55	·10	2·25	40	17·85	1·31		0·75	·32	6·78
50	40·51	1·97		13·45	·11	2·33	50	19·16	1·30		0·43	·33	6·85
349 0	+23 42·48	1·96	+·127	−7 13·34	·12	+2·41	359 0	+25 20·46	1·29	+·123	−7 0·10	·33	+6·92
10	44·44	1·96		13·22	·11	2·48	10	21·75	1·27		6 59·77	·33	6·99
20	46·40	1·94		13·11	·12	2·56	20	23·02	1·26		59·44	·34	7·06
30	48·34	1·93	·127	12·99	·13	2·64	30	24·28	1·25	·122	59·10	·34	7·13
40	50·77	1·92		12·86	·13	2·72	40	25·53	1·24		58·76	·35	7·20
50	52·69	1·90		12·73	0·13	2·80	50	26·77	1·23		58·41	0·35	7·27
350 0	+23 54·09		+·126	−7 12·60		+2·88	360 0	+25 28·00		+·122	−6 58·06		+7·34

The "Angle between the circle of declination and the sun's axis" corresponds to the assumed obliquity of the ecliptic 23° 27′·50. If the true obliquity is $=23° 27'·50+ε$, the needed correction may be found by means of the following Table, the factor of ε being + or −, according as the argument is on the left or the right side.

☉		Correction.	☉		☉		Correction.	☉	
0°	360°	+1·000 ε−	180°	180°	45°	315°	+0·676 ε−	135°	225°
1	359	1·000	179	181	46	314	·663	134	226
2	358	0·999	178	182	47	313	·650	133	227
3	357	·998	177	183	48	312	·637	132	228
4	356	·997	176	184	49	311	·623	131	229
5	355	+ ·995 −	175	185	50	310	+ ·610 −	130	230
6	354	·993	174	186	51	309	·596	129	231
7	353	·991	173	187	52	308	·582	128	232
8	352	·988	172	188	53	307	·569	127	233
9	351	·985	171	189	54	306	·555	126	234
10	350	+ ·982 −	170	190	55	305	+ ·540 −	125	235
11	349	·978	169	191	56	304	·526	124	236
12	348	·974	168	192	57	303	·512	123	237
13	347	·970	167	193	58	302	·497	122	238
14	346	·965	166	194	59	301	·483	121	239
15	345	+ ·960 −	165	195	60	300	+ ·468 −	120	240
16	344	·955	164	196	61	299	·453	119	241
17	343	·949	163	197	62	298	·438	118	242
18	342	·943	162	198	63	297	·423	117	243
19	341	·936	161	199	64	296	·408	116	244
20	340	+ ·929 −	160	200	65	295	+ ·393 −	115	245
21	339	·922	159	201	66	294	·378	114	246
22	338	·915	158	202	67	293	·363	113	247
23	337	·907	157	203	68	292	·348	112	248
24	336	·900	156	204	69	291	·332	111	249
25	335	+ ·891 −	155	205	70	290	+ ·317 −	110	250
26	334	·883	154	206	71	289	·301	109	251
27	333	·874	153	207	72	288	·286	108	252
28	332	·865	152	208	73	287	·270	107	253
29	331	·856	151	209	74	286	·254	106	254
30	330	+ ·846 −	150	210	75	285	+ ·239 −	105	255
31	329	·836	149	211	76	284	·223	104	256
32	328	·826	148	212	77	283	·207	103	257
33	327	·816	147	213	78	282	·191	102	258
34	326	·806	146	214	79	281	·176	101	259
35	325	+ ·795 −	145	215	80	280	+ ·160 −	100	260
36	324	·784	144	216	81	279	·144	99	261
37	323	·773	143	217	82	278	·128	98	262
38	322	·761	142	218	83	277	·112	97	263
39	321	·753	141	219	84	276	·096	96	264
40	320	+ ·738 −	140	220	85	275	+ ·080 −	95	265
41	319	·726	139	221	86	274	·064	94	266
42	318	·714	138	222	87	273	·048	93	267
43	317	·701	137	223	88	272	·032	92	268
44	316	·689	136	224	89	271	·016	91	269
45	315	+0·676 ε−	135	225	90	270	+0·000 ε−	90	270

THE ALCALDE'S HOUSE AND THRASHING FLOOR.

MR. DE LA RUE'S LODGINGS.

THE VILLAGE OF RIVABELLOSA.

Printed by the ordinary Letterpress, from a Block produced by means of Photography and Electrometallurgy.
Absolutely untouched by the graver.

THE BAKERIAN LECTURE.

ON

THE TOTAL SOLAR ECLIPSE

OF JULY 18TH, 1860,

OBSERVED AT

RIVABELLOSA, NEAR MIRANDA DE EBRO,

IN SPAIN.

BY

WARREN DE LA RUE, Esq., Ph.D., F.R.S.,

Hon. Sec. Royal Astron. Soc., Treasurer Chem. Soc. &c.

From the PHILOSOPHICAL TRANSACTIONS.—Part I. 1862.

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1862.

XVIII. The Bakerian Lecture.—*On the Total Solar Eclipse of July 18th, 1860, observed at Rivabellosa, near Miranda de Ebro, in Spain.*

By Warren De La Rue, *Esq., PhD., F.R.S., Hon. Sec. Royal Astron. Soc., Treasurer Chem. Soc., &c.*

Received January 30,—Read April 10, 1862.

My attention was first called to the Solar Eclipse of 1860, in the latter part of the year 1858, on the occasion of my visiting Russia, when Dr. Mædler placed in my hands a copy of his anticipative pamphlet, entitled "L'Eclipse Solaire du 18 Juillet, 1860."

This paper contained a Map of Spain, with certain lines indicating the position of the central path of the moon's shadow, the limits of totality, and its epoch at various localities; and it occurred to me, on perusing it, that, if circumstances should permit of my observing the eclipse, Santander would be very convenient for the disembarcation and erection of the instruments I should, in all probability, require for photographic observations, to the prosecution of which my successful researches in astronomical photography led me to think I ought to devote myself. On communicating my plans to Mr. Vignoles, he strongly recommended me to cross to the southern side of the Pyrenees in order to avoid the mists which are caused by the condensation of vapours from the ocean against the northern slopes of the mountains. Subsequently Mr. Vignoles published an eclipse-map of Spain on a very large scale, and I selected Miranda for my station; but he suggested that I should place my observatory at Rivabellosa, about two miles from that town.

It is fortunate that I changed my station from Santander to Rivabellosa, as many of those astronomers who selected the former place were prevented by the state of the atmosphere from observing the eclipse.

On my journey to Russia, I stopped at Königsberg and made the acquaintance of Dr. Luther, who showed me the Daguerreotype of the total eclipse of 1851, which had been taken by Dr. Busch with the Königsberg heliometer. Great credit is due to Dr. Busch for that successful pioneering experiment, more especially when due allowance is made for the uncertainty then existing as to the brilliancy of the prominences, and for the state of the photographic art at that epoch. In the interval of seven years, however, astronomical photography had made great progress; and I recollect being much struck with the very indifferent definition of the protuberances in the Daguerreotype, from which I inferred the impracticability of deriving any conclusive evidence respecting the nature of such appearances from photographs, unless more distinct ones could be obtained. The inspection of the Königsberg Daguerreotype subsequently exercised some influence on my plan of procedure. Discarding all thoughts of employing the Daguerreo-

type process, because the collodion process was far more sensitive and convenient, I chose the latter as best suited to my purpose, although I knew perfectly well, from experience, how frequently the collodion-film is rendered defective by specks, streaks, and even minute holes. It was open to me to employ an achromatic or a reflecting telescope of ordinary construction, and to place the sensitive plate in the principal focus; but I was aware that the largest telescope I could possibly take with me would only give an image of a very moderate size, and that any of the before-named defects in the collodion might fall over and obliterate, or so confuse the impression of any prominence in one photograph, as to render its identification with its impression in a subsequent photograph a matter of impossibility. These considerations led me to think that it would be very desirable to employ the Kew photo-heliograph, because in this instrument the primary focal image of the sun is enlarged from about half an inch in diameter to nearly 4 inches, which is a scale amply sufficient to counterbalance the disadvantages of the collodion process; but, on the other hand, the light is thus attenuated sixty-four times, besides being absorbed to some extent in passing through the two lenses composing the secondary magnifier, an ordinary Huyghenian eyepiece; and this question consequently presented itself, Would it be possible with such an enfeebled image to get even a single impression during the whole duration of the totality? This was an extremely doubtful matter. By employing the Kew heliograph one would evidently run the risk of returning without any pictures of the *totality*, however many might be procured of the other phases of the eclipse*.

At the meetings of the Astronomical Society, and on other occasions, I made inquiries of those astronomers who had witnessed the eclipse of 1851, respecting the intensity of the light of the corona and red flames, as compared with that of the moon, and the relative brightness of the one to the other; but their answers did not tend to increase my hopes in respect of the possibility of procuring photographs of the totality by means of the Kew instrument. The general impression I formed from the information thus derived was, that the light emitted by the corona and red flames, taken together, was about equal to that of a full moon—less rather than greater; but no one recollected precisely the brightness of the prominences as compared with that of the corona. With this imperfect information as a guide, an attempt was made at Kew to photograph the moon, but not the slightest impression could be procured of our satellite by an exposure of the sensitive plate, during one whole minute†, to its image in the heliograph. My expectation of success in getting pictures of the totality was not great after this trial; nevertheless I still thought it desirable to carry on the experiment to the end, on account of the value of the results if I should fortunately succeed. It occurred to me several times to fit up also a photographic apparatus to an achromatic telescope, but I finally concluded that to attempt too many things would be sure to result in complete failure. I endeavoured, however, to stimulate other astronomers to

* Report on Celestial Photography, by the author, in the Reports of British Association, 1859, p. 152.

† While this paper was passing through the press a very faint impression of the moon was procured with the Kew heliograph in three minutes, with chemicals which gave a very strong impression of it in four seconds in the focus of my reflector of 13 inches aperture and 10 feet focal length.—August 1862.

make photographic experiments in the manner which I have indicated, as offering a greater probability of at least a partial success, so that the chances of obtaining pictures might be multiplied. With this object, I circulated as rapidly as I could my Report to the British Association on "Celestial Photography," which passed through the press in May 1860, and of which copies were extensively sent both to English and foreign astronomers at the latter end of May and the beginning of June.

I have now in this narrative to go back some months earlier than the period just alluded to, in order to connect it with the Himalaya Expedition, an expedition originating solely with, and organized by, the Astronomer Royal. When the year 1859 was drawing to a close, and I was turning my thoughts to the preparation which would be required for July 1860, Mr. Airy mentioned that, if I had any intention of observing the eclipse, he might possibly be in a position to afford me some facilities for so doing, as he had it in contemplation to make an application to the Admiralty for a ship to convey intending observers to Spain, in the event of a sufficient number of astronomers expressing their willingness to join the expedition which he intended to organize. I expressed the satisfaction I felt in learning that he, the official head of astronomy in England, was willing to take the matter in hand, because I felt persuaded that, under his general direction, the expedition would prove a successful one; and I at once volunteered to form one of his party.

It was intimated to me that, in the event of my taking charge of the Kew heliograph, I should not be expected to entail upon myself the expenses of fitting it up for the object contemplated, or the personal expenses of the assistants who might accompany it, it having been from the first intended, that a grant from the Government Fund should be asked for to defray these charges. When, therefore, I had finally decided on taking charge of the instrument, I was requested to propose such a sum as I thought fully adequate to the purpose, and I named £150, which was granted. The entire expenses of the photographic expedition amounted to more than three times that sum, the balance being defrayed by myself.

The actual preparations were commenced at the latter end of January 1860, first of all by Mr. Beckley, the mechanical assistant of the Kew Observatory, and were continued, so far as his other occupations would permit, until the month of June; but, in spite of every exertion on his part, so much remained to be done, that in June I engaged Mr. Reynolds (now my private photographic assistant) to aid in completing the arrangements. My party, besides myself, was, after a few changes, thus finally constituted:— Mr. Beckley, Mr. Reynolds, Mr. Downes, and Mr. E. Beck.

Among the preparations to be made was a stand for the telescope, the cast-iron pedestal of the Kew heliograph being too heavy for convenient transport. It was necessary, moreover, to make some contrivance for supporting the frame of the polar axis in a position adapted to certain limits of latitude, within which I might fix my station; and it was thought that this could be best arranged by making a new cast-iron pedestal composed of several pieces which took apart for the convenience of carriage*.

* This iron stand has been left *in situ*, and thus marks the precise locality of my observatory.

Originally, merely a temporary tent in which to develope the photographs was procured; but when it was known that H.M.S. 'Himalaya' would be placed at the disposal of the Astronomer Royal, I put this aside, and caused a complete photographic observatory to be constructed, part to contain the heliograph with a removable roof, and part divided off and fitted up as a photographic room, with a cistern, to be filled from the outside, a sink, and with tables and shelves to hold the apparatus and photographs. This observatory took to pieces, and every part was marked when in its place, so that no time need be lost in putting it together again in its destined position. Besides the ordinary roof, there was another covering, consisting of strong canvas, supported at the distance of about three feet from the walls and roof of the developing-room. The object of this was to prevent the overheating of the photographic room, a circumstance most detrimental to photography. This canvas was kept wetted with water, in order that the evaporation might lower the temperature of the stratum of air between it and the observatory, and it fulfilled the object perfectly. The canvas, when the observatory was not in use, was drawn over the room containing the heliograph, and protected the instrument from rain.

The print exhibits the arrangement of the observatory, when secured after the day's work. The position of the canvas, and the simple arrangement for maintaining it at the proper distance from the house, and also the outside cistern, are well shown in the picture, which is copied from a photograph taken on the occasion of Mr. AIRY's visit to my station. When the observatory was at work, the canvas was removed from the front (the south side) and tied back as far as the upright which is seen on the western side, the top boards also being removed. The front boards were of a height which admitted of our observing the sun above them whenever it was desirable to do so.

Photographic chemicals were prepared in duplicate; part of the collodion intended to be used was mixed with the iodizing solution in London, and after subsidence was carefully decanted previous to packing, in order to avoid the defects before alluded to; but collodion and iodizing solution were also taken separately, so that some might be prepared on the spot, and used, if found free from defects, in that state of extreme sensitiveness which exists in collodion freshly iodized with the potassium iodizer. Nitrate-of-silver baths, prepared in the ordinary way with crystallized nitrate of silver, were taken, and were used in depicting the several phases of the eclipse, with the exception of those of totality. In taking the latter pictures the baths used were made with nitrate of silver which had been fused carefully in my own laboratory, and were so extremely sensitive that they would give photographs of the full moon in the focus of my reflector in less than a second of time, while with the usual bath five seconds were barely sufficient to give a picture of similar intensity.

As few astronomers perhaps are aware of the number of materials required for such an expedition, I here give the list of contents of one of the boxes of chemicals.

Packages.	Contents.
3	Half-pint bottles of Collodion.
1	Four-ounce Bottle of Collodion, iodized.
1	Half-ounce Bottle of Pyrogallic Acid.
1	Six-ounce Bottle of Acetic Acid.
1	$1\frac{1}{2}$-pound Bottle of Hyposulphite of Soda.
1	Case containing Oxide of Silver and dilute Nitric Acid, in separate bottles, for correcting the bath, in case of need.
2	24 oz. of Nitrate-of-silver Bath.
1	2 oz. Crystals Nitrate of Silver.
1	4 oz. fused Nitrate of Silver.

Packages.	Contents.
1	$\frac{1}{2}$ oz. Iodide of Potassium.
1	Ounce Measure.
1	Gallon Distilled Water.
1	Set of Scales and Weights.
3	Plate-drainers.
1	4 oz. of Tripoli.
1	Packet Cotton Wool.
1	Glass Funnel.
1	Retort Stand.
1	Lantern.
3	Bottles of Varnish.
	Test Papers.
	Filtering Paper.
4	8-oz. Mixing Glasses for Collodion.

The apparatus, when completed, weighed 34 cwt., and was made up into thirty pack-

ages for convenience of transport. Among the miscellaneous requisites were included:—distilled water weighing 139 lbs.; engineers' and carpenters' tools weighing 113 lbs.; lanterns, lamp-oil, spirit-lamp, and spirits of wine, weighing together 73 lbs.; a small stove and kettle for boiling water, and, lastly, some preserved provisions, in case the party should be compelled to encamp for a few days. Owing, however, to the excellent arrangements most kindly made by Mr. VIGNOLES, the latter were quite unnecessary.

As my plans became matured, it occurred to me that it would be desirable to make determinations of geographical position; and I therefore borrowed from the Kew Observatory a small transit theodolite with 6-inch altitude and azimuth circles, both reading with the verniers only to one minute of arc. The optical part of the instrument was found to be very indifferent, and the readings of the altitude circle were, from some cause, not so accordant from time to time as they ought to have been. I took with me also three chronometers—a box chronometer, a pocket chronometer, both indicating Greenwich mean time, and my journeyman sidereal chronometer.

I was induced to make preparations for eye-observations (which I did not originally contemplate), partly in order that I might be in a position to interpret from my own sketches and recollections the results of the photographs, and partly because in case I should fail in making photographs, I might still be able to contribute something to the series of optical observations. I therefore took with me a beautiful achromatic of 3 inches' aperture, which Mr. DALLMEYER had kindly lent me for the occasion. This telescope was mounted by Messrs. TROUGHTON and SIMMS on a most convenient and steady altazimuth-stand, designed by the Astronomer Royal. The equatorial movement was effected by the joint action of two radius bars, which enabled me to keep the sun exactly within a tangential square, which I had had ruled upon glass and placed in the focus of an eyepiece to be described hereafter.

Lastly, through the kindness of Messrs. ELLIOTT and Mr. CASELLA, I obtained the loan of some meteorological instruments. Messrs. ELLIOTT lent me one of their excellent aneroid barometers. Mr. CASELLA lent me a marine barometer and a standard thermometer, both verified at Kew, the readings of which were used in the reductions of the astronomical observations.

The apparatus was sent to Plymouth on the 5th of July, whence we set sail on the 7th; on the 9th we reached our destination. Mr. VIGNOLES met the 'Himalaya' in a small steamer which he had chartered to convey ashore the astronomers who intended to land at Bilbao, with their apparatus and luggage; but I am placed under a further obligation to him, not only for his kind and liberal hospitality during my stay at Bilbao, but also for dispatching my apparatus, as soon as it was landed, to Rivabellosa, which is situated at a distance of seventy miles from the port of Bilbao, and is only accessible through a pass difficult for the transmission of heavy baggage.

On the evening of the 10th we left Bilbao in a diligence which I had engaged to convey my party to Rivabellosa, at which place we arrived on the next day, after a journey very trying to our chronometers.

The instruments reached Rivabellosa on the evening of the 11th; the previous part of the day had been occupied in taking a general survey of the country around the village, with the object of selecting a site whereon to erect our observatory, and I at length settled on one of the thrashing-floors* which are to be seen in great numbers in that country in the open fields. It was about 60 feet in diameter, and close to the road, which we found to be a great convenience, inasmuch as the water required for our use had to be brought from a distance. Moreover, it was level, and extremely hard and dry. I had hardly selected this site when I learned, with some concern, that the harvest had commenced, and that the proprietor intended to make use of the floor on the morrow for his thrashing operations, which it is the custom of the country to complete immediately after the reaping. However, Don SIMON, land-surveyor of the Bilbao and Tudela Railway, who explained this to me, kindly undertook to negotiate for the hire of the station; but the owner, when informed that his thrashing-floor was the best adapted for my purpose of any place I had seen, at once said that it was quite at my disposal, and, although he had to convey his grain to a distance, refused any remuneration.

The instruments were conveyed to the thrashing-floor, and the transit theodolite unpacked in time to make an observation of the sun soon after 10 o'clock on the morning of the 12th. By the evening the observatory was erected and in actual operation, and a photograph of the sun was obtained on the 14th. To my staff was at last added Mr. S. CLARK, who had acted as interpreter, and who kindly volunteered his assistance during the eclipse. And I am greatly indebted to the gentlemen composing my staff for their most efficient assistance. With a self-denial hardly to be expected under the circumstances, each carried out steadily his allotted task, and thus contributed to a result which is most gratifying, after so much preparation and trouble.

Upwards of forty photographs were taken during the eclipse, and a little before and after it,—two being taken during the totality, on which are depicted the luminous prominences, with a precision as to contour and position impossible of attainment by eye-observations.

Photographs of the sun were taken on the two days succeeding the eclipse, namely, the 19th and 20th, and the instruments were then taken down and packed.

On the 26th the Himalaya Expedition re-embarked on board the 'Himalaya,'—myself, staff, and baggage being reconveyed to the vessel from Bilbao through the kindness of Mr. VIGNOLES, who accompanied us to England. On the 28th we landed at Portsmouth. I must here take occasion to express my best thanks to Captain SECCOMBE and the officers of the 'Himalaya' for their great kindness during the outward and homeward voyage. My thanks are also due to Señor MONTESINO, Chairman of the Bilbao and Tudela Railway, for assistance rendered; also to Don SIMON, and to Mr. BENNISON and Mr. PRESTON, gentlemen belonging to Mr. VIGNOLES's staff.

* In the accompanying print a thrashing-floor, similar to the one I employed, is represented. The Plate is inserted partly with the object of calling attention to Mr. PAUL PRETSCH's phototype process, which I have recently employed to furnish representations of sun-spots. (See Monthly Notices Roy. Ast. Soc. vol. xii. p. 278.)

After having obtained the photographs and got them home safely, my work was only begun. I knew that they contained in themselves most valuable records; but it did not, in the first instance, appear so clearly how I could turn them to account. The two totality pictures presented the most interest, and to them I first turned my attention; and as it was evident that no measurements ought to be made on the originals, I then bethought me of the best means of multiplying them. In the first instance, I got some enlarged positive copies photographed by Mr. DOWNES, and, made some little progress in measuring them; but I soon found that I should require others, and, on attempting to have some made a little later in the year, I experienced an amount of difficulty I never could have anticipated. The original negatives proved to be so extremely intense, that nothing short of unobscured sunlight would penetrate them and reveal their details; so that it was only by working for many selected days with Mr. DOWNES, that I succeeded in getting a sufficient number of positive copies for my purpose. Those who remember how remarkably dull and wet the year 1860 was in England will readily understand that the selected days were few and far between, so that it was fast approaching winter before I had got on much with the work on the photographs. I also had recourse to the albumen process, and obtained a few copies of the size of the original by superposition, without the intervention of the camera. These were made in my presence, at Messrs. NEGRETTI and ZAMBRA'S, and from these positives some negatives were taken. Although these copies did not aid me greatly, it was fortunate they were taken; for in course of time the original negative No. 26, the second of totality, gave indications of decay, and on attempting to save it by revarnishing it, the collodion expanded, and crinkled up so much that, except as a record of what was done, the original negative is spoiled. I have protected it from further injury by cementing it with Canada balsam to a second glass plate; but one of the albumen negatives must now supplement it, if more copies are ever taken by direct superposition. Enlarged negatives, however, exist; but, as something is always lost in copying, the damage to the original negative is unfortunate *.

Measurements of the enlarged positives on glass of the totality pictures soon proved to me that the most accurate results could be obtained by measuring the photographs of the other phases, and that these results would indicate the path of the moon, and the position of the centres at the epoch of totality, independently of any determinations of geographical position. For this object it became necessary to measure the original negatives, because the slightest deviation of the optical axis of the copying camera from a right angle to the plane of the sensitive plate, or the least eccentricity, would cause a distortion of the cusps. I had, therefore, to devise an instrument for measuring the photographs; and having considered how the object could be effected, I put one in hand with Messrs. TROUGHTON and SIMMS, who constructed it for me with their usual skill and precision. After the instrument had been made, it was found to be convenient that some of the parts should be provided with a means of adjustment; so that although it was commenced in February of 1861, it was not until July 18th that it was

* The whole of the original negatives have been deposited with the Astronomer Royal.

completely finished and ready for use. Since that time, every spare moment has been devoted to the final accomplishment of this work; and, taking into account the interruptions I am subject to, I feel convinced that it could not have been done in less time, although I candidly confess that the delay in sending in this Report must appear scarcely warranted.

Determination of the Geographical Position.

Previous to starting for Spain, I made certain preparations for facilitating the after-operations which I might have to carry out; for I knew that the time allowed for getting the instruments into position would not be more than sufficient, even if each day permitted of observations being made. For this reason, I computed, with the formula

$$\frac{\sin(\alpha\mp\lambda)}{\sin\alpha} \quad (\alpha = \text{the polar distance, } \lambda = \text{the colatitude}),$$

a series of star constants for all the stars likely to be visible in my instrument. I also computed a table of corrections, to be applied to the times of equal altitudes of the sun for intervals of two, three, four, five, and six hours, for each day from July 12 to July 22; and similar corrections to the azimuths of equal altitudes, to enable me to lay off at once a meridian line and erect a mark. My star constants did not, however, prove of much service; for it was rarely that I could get a glimpse of the stars; so that on only two occasions was I enabled to make any observations at all, and then only with the greatest difficulty, although I watched patiently for opportunities through or between the clouds.

I have already stated that I took with me three chronometers. My journeyman sidereal chronometer, Leplastrier 2915, is a very old one. In consequence of the wear of the fusee, this chronometer, which is an eight-day one, varies in its daily rate from 8·6 seconds to 17 seconds, losing; but during long periods the rate is pretty uniform, as will be seen from the following observations:—

Leplastrier 2915.

	sec.
From June 30 to July 3, losing daily	10·36
From July 3 to July 30, losing daily	12·51
From July 30 to August 7, losing daily	12·06
From August 7 to August 17, losing daily	11·29
On July 3, 21^h 24^m, it was fast of Cranford sidereal time	194·8
Cranford observatory is west of Greenwich in longitude	97·5
Hence, on July 3, 21^h 24^m, Leplastrier No. 2915 was fast of Greenwich sidereal time	97·3
	194·8
On July 30, 6^h 30^m, it was slow of Cranford sidereal time . . .	138·0

The pocket chronometer, Frodsham No. 9768, was found to have the following rates and errors:—

	sec.
From June 26 to June 29. its daily rate was losing	1·05
From June 29 to June 30, its daily rate was losing	2·84
From June 30 to July 3, its daily rate was losing	2·00
On June 26, 15^{h}, it was slow of Greenwich mean time	3·0
On July 3, 15, it was slow of Greenwich mean time	15·0

From these data, the mean daily rate was 1·71 seconds losing. On the 17th or 18th of July this chronometer tripped, most likely in consequence of its having been touched by the inmates of my lodgings; and it was therefore useless to make any determination of its error on my return from Spain.

From a comparison with the box chronometer to be next mentioned, for the loan of which I was indebted to the kindness of Mr. FRODSHAM, I estimated the error on Greenwich mean time of Frodsham 9768 to be 3·2 sec. slow, for July 3, 15^{h}, instead of 3 sec., as found by observation. The comparison was made on June 25, 22^{h}: two hours later Mr. ELLIS found the box chronometer, Frodsham

	sec.	
No. 3094, to be on June 26, 0^{h}	1·9	slow of Greenwich mean time.
In two hours 3094 would have gained	0·08	
At the time of comparison 9768 was slow of 3094	0·50	
Between the comparison and the ascertaining of the error of 9768, namely 17 hours, the latter would lose	0·74	
Estimated error of Frodsham 9768, on June 26, 15^{h}	3·22	

This difference between 3·2 sec. and 3·0 sec. might have been occasioned by the journey of No. 3094 to Greenwich, but in any case was so small that, for the subsequent calculations, I retained without correction the error afterwards determined by observation on July 3, 15^{h}, when Frodsham 9768 was slow of Greenwich mean time 15·0 sec.; whence on July 5, 0^{h}, its error would have been 17·3 sec. slow of Greenwich mean time.

The box chronometer, Frodsham No. 3094, was (through the kindness of the Astronomer Royal) compared at Greenwich by Mr. ELLIS, whose determination of its errors are given below.

	h	m	sec.	
June 26 . . .	0	0	1·9	slow of Greenwich mean time.
June 27 . . .	0	0	1·0	
June 28 . . .	0	0	0·5	
June 29 . . .	0	0	1·3	fast of Greenwich mean time.
June 30 . . .	0	0	2·3	
July 1 . . .	0	0		
July 2 . . .	0	0	3·6	
July 3 . . .	0	0	4·5	

The average daily rate of this chronometer was therefore gaining 0·91 sec.; and assuming this rate to have continued, on July 5 0^h its error would have been fast of Greenwich mean solar time 6·3 seconds.

On the supposition that the pocket chronometer would continue to lose 1·71 sec. daily, and that the box mean-time chronometer would continue to gain daily 0·91 sec.
box chronometer Frodsham 3094 would gain over Frodsham 9768 . . 2·62 secs. daily.

The subjoined Table contains the assumed errors of each chronometer, the estimated difference between the two chronometers, and the difference actually observed as nearly as possible at noon of each day—the observation being reduced to noon:—

Date.	Assumed error of Frodsham 3094.	Assumed error of Frodsham 9768.	Estimated difference between 9768 and 3094.	Observed difference between 9768 and 3094.
	sec.	sec.	sec.	sec.
July 5.	fast 6·3	slow 17·3	−23·6	−24·5
July 6.	fast 7·2	slow 19·0	−26·2	
July 7.	fast 8·1	slow 20·7	−28·8	
July 8.	fast 9·0	slow 22·4	−31·4	
July 9.	fast 9·9	slow 24·1	−34·0	−35·0
July 10.	fast 10·8	slow 25·8	−36·6	−37·0
July 11.	fast 11·7	slow 27·5	−39·2	−37·5
July 12.	fast 12·6	slow 29·2	−41·8	−37·5
July 13.	fast 13·6	slow 30·9	−44·5	−38·5
July 14.	fast 14·5	slow 32·6	−47·1	−40·0
July 15.	fast 15·4	slow 34·3	−49·7	−41·5
July 16.	fast 16·3	slow 36·1	−52·4	−42·5

On examining the two box chronometers immediately after our arrival at Rivabellosa, Leplastrier 2915 was found to be apparently uninjured, but I was chagrined to find that Frodsham No. 3094 had been most severely disturbed by the joltings of our vehicle, notwithstanding the protection of its outside padded case, and an extra precaution I had taken to press shavings into its own case, to keep it firm in its place. The cap of the glass had become unscrewed, the glass had shaken out, and the chronometer itself, shifting from its normal position, had risen out of its seat; fortunately, however, the glass could not move far, on account of the wadding, and the hands were consequently uninjured. I succeeded in replacing the chronometer, and in putting the glass into its frame; but it thenceforward took up an entirely new rate, as was evident on comparing the differences between its readings and those of the pocket chronometer. An inspection of the foregoing Table shows that up to the 10th the two chronometers maintained the average rate assigned to each; for example, the computed difference minus the observed difference on that day amounted to only −0·4 second. After my return to England, chronometer No. 3094 was, with the Astronomer Royal's kind permission, again compared by Mr. Ellis, who found the following errors from Greenwich mean time:—

For Frodsham 3094.

	h	m	secs.
August 10	0	0	2·8 slow.
August 11	0	0	3 slow.
August 13	0	0	2·7 slow.
August 14	0	0	3 slow.
August 15	0	0	2·2 slow.
August 16	0	0	2·6 slow.
August 17	0	0	2·8 slow.
August 18	0	0	2·7 slow.
August 20	0	0	2·5 slow.

its average daily rate being losing 0·03 second, whereas, before starting, it was gaining 0·91 second.

On the 16th of July, Mr. OTTO STRUVE, Dr. WINNECKE, and Lieut. OOM visited my station; and I took advantage of their doing so, to make a comparison of chronometers. Dr. WINNECKE estimated the error of Frodsham No. 3094 to be fast of Greenwich mean time 7·5 seconds; consequently as the pocket chronometer Frodsham No. 9768 was slow of No. 3094 42·5 seconds, it follows, from this comparison, that it was —42·5 seconds +7·5 seconds =35 seconds slow of Greenwich mean time, which differs by only —1·1 second from the error assigned to it, by applying its mean daily losing rate of 1·71 second.

It appears, therefore, that the pocket chronometer could be relied on up to the 16th of July. On correcting the assumed error from Greenwich mean time of No. 3094 by comparisons with the pocket chronometer, we obtain the following:—

Frodsham No. 3094.

	Computed error from Greenwich mean time, taking No. 9768 as the standard.	Assumed error from Greenwich mean time applying its average rate.
July 9	fast 10·9 seconds	fast 9·9 seconds
July 10	fast 11·2 seconds	fast 10·8 seconds
July 11	fast 10·0 seconds	
July 12	fast 8·3 seconds	
July 13	fast 7·6 seconds	
July 14	fast 7·4 seconds	
July 15	fast 7·2 seconds	
July 16	fast 6·4 seconds	

With the advantage of the comparison made on the occasion of Mr. STRUVE's visit, I have confidence in assuming the error of Frodsham 3094 to have been from +6·4 to +7·5 seconds, say +7 seconds, on July 16 at noon.

On the 19th the Astronomer Royal and his party honoured me with a visit, and I had the great satisfaction of hearing from our leader that he was well satisfied with the suc-

cess of my photographic operations, and also with the arrangements of the observatory, and the many preparations which had been made to secure the result.

At 2^h 30^m, a comparison was made between Mr. AIRY's pocket chronometer Molyneux No. 1007 and the box chronometer Frodsham No. 3094; Molyneux was slow of Frodsham 3094 43 seconds.

Molyneux 1007 was slow of Greenwich mean time,

	h	sec.	
On July 16 . .	23	28·8	losing daily 7·2 seconds.
July 17 . .	22	35·7	gaining daily 2·7 seconds.
July 18 . .	22	33·0	

Applying the latter rate, Molyneux would appear to have been, on July 19, 2^h 30^m, 32·5 seconds slow, and consequently Frodsham 3094 10·5 seconds fast of Greenwich mean time. I believe that Molyneux 1007 could not be greatly depended on; but, the comparison of chronometers having been made, I place the result on record, although I am not able to make it accord with the other observations within several seconds.

Observations.

The following observations were made with the transit theodolite. During the day the instrument had to remain exposed to the sun; and this caused the several parts to expand very unequally, and kept the bubble in the level always in motion—a circumstance which proved very troublesome.

Estimation of Longitude.

July 12. Four pairs of reduced observations of equal altitudes of the sun showed that at local mean noon

Frodsham 3094 was fast of local mean time . . . 11 min. 51·9 sec.

July 14. Two pairs of reduced observations of equal altitudes of the sun showed that at local mean noon

Frodsham 3094 was fast of local mean time . . . 11 min. 51·3 sec.

With reduced observations of the azimuths of equal altitudes of the sun on the 12th and the 14th, northern and southern adjustable meridian marks were placed, the first against a building, the second against some trees; both sufficiently distant to give distinct vision of the mark, which was a cross $\times$ of wood, moveable in a top and a bottom groove in a wooden frame.

Attempts were made on the night of the 13th to obtain observations of stars; but the weather was too cloudy; by dint of perseverance, however, I did manage to get, through breaks in the clouds, the meridian altitude of α Lyræ, and an altitude of the pole star out of the meridian, presently to be referred to in the determinations of latitude.

On the night of the 14th I was more fortunate, and was able to obtain observations of a high and low star, and finally to adjust the meridian marks by means of an observation of δ Ursæ Minoris on the meridian. As soon as the observation of δ Ursæ Minoris

was made, an assistant at each of the marks held a lantern near it, so that being illuminated I might see it with the theodolite and thus be enabled to make signals to them for the permanent adjustment of the marks, which was successfully accomplished. The following day being Sunday, no work was done; but on Monday Mr. Preston volunteered to aid me in projecting my meridian towards the station of the Astronomer Royal at Pobes. Using, as a signal flag, a bed sheet, which was not at all larger than was necessary in order to be well seen, I was able to direct Mr. Preston where to erect a staff with a similar appendage, in the line of my meridian, towards the north, and at a distance of about seven miles from Rivabellosa. Mr. O. Struve, as I before said, visited us on the 16th and undertook to work out the geodetic survey, which it was agreed should be made to connect the Pobes and Rivabellosa stations.

July 14. Observations of α Scorpii and ζ Herculis, when reduced, showed that at 16 hour 28 min.

Leplastrier 2915 was fast of local sidereal time . . . . 11 min. 1·7 sec.

The weather afforded no other opportunity for star observations for longitude determinations until the night of the 18th, when I was too much fatigued to avail myself of it.

July 16, 0 h. A transit of the sun showed that

Frodsham 3094 was fast of local mean time . . . . . . 11 min. 49·9 sec.

July 20, 0 h. A transit of the sun showed that

Frodsham 3094 was fast of local mean time . . . . . . 11 min. 41·5 sec.

July 20, 8 h. 0 min. sidereal time. The transit of the sun being observed simultaneously with the sidereal chronometer, showed that

Leplastrier 2915 was fast of local sidereal time . . . . 9 min. 55·8 sec.

From the foregoing observations are derived the following results.

Frodsham No. 3094.

	Fast of Rivabellosa, mean solar time.			Daily rate.	Error on Greenwich mean time as estimated by comparison with Frodsham 9768.
	h	m	sec	sec.	sec.
July 12th . .	0	11	51·9		Fast 8·3
				Losing 0·3	
July 14th . .	0	11	51·3		Fast 7·4
				Losing 0·7	
July 16th . .	0	11	49·9		Fast 6·4
				Losing 2·1	
July 20th . .	0	11	41·5		

whence the Longitude was West of Greenwich

	m	sec.
July 12 . . .	11	43·6
July 14 . . .	11	43·9
July 16 . . .	11	43·5
Mean . . .	11	43·7

Taking Dr. Winnecke's estimate of the error of Frodsham No. 3094 on the 16th, namely, 7·5 seconds fast of Greenwich, we get for the longitude

West 11 min. 42·4 seconds

Applying the average daily losing rate of 12·51 sec. since July 3rd, 21 h. 24 min. for Leplastrier, we derive the following results from the observations made with that chronometer:—

Leplastrier No. 2915

	h	m	Was fast of local sidereal time. m	sec.	Error on Greenwich sidereal time by applying mean daily rate.	m	sec.
July 14 . .	16	47	11	1·7	Slow	0	37·9
July 20 . .	8	0	9	55·8	Slow	1	48·4

whence the longitude was West of Greenwich

	m	sec.
July 14 . .	11	39·6
July 20 . .	11	44·2
Mean .	11	41·9

By combining all the foregoing results, and taking the arithmetical mean, we obtain for my Observatory at Rivabellosa

		m	sec.
		11	43·7
		11	42·4
		11	41·9
the longitude	West	11	42·7

Observations for Latitude.

July 12. The reduced zenith distance of the sun's upper limb, when on the meridian, gave as the latitude of Rivabellosa

N. 42° 42′ 37″

July 13. An observation of α Lyræ on the meridian and of *Polaris* out of the meridian, when reduced, gave for the latitude freed from error of the level,

N. 42° 42′ 19″.

July 14. An observation of the zenith distance of the sun's upper limb previous to the meridian passage at the hour angle 24° 5′ 15″ gave, when reduced, the latitude

N. 42° 41′ 48″.

July 20. The reduced zenith distance of the sun's upper limb, when on the meridian, gave the latitude

N. 42° 41′ 17″.

Combining the foregoing determinations of latitude, we obtain

		°	′	″
July 12. Observations of sun		42	42	37
July 13. Observations of stars		42	42	19
July 14. Observations of sun		42	41	48
July 20. Observations of sun		42	41	17
as the mean	Latitude N.	42	42	

The foregoing numbers are not so accordant as I could desire; but they are, I believe, as good as could have been obtained with the instrument, particularly under the circumstance of its continual exposure to the sun during its employment in the day-time.

Elevation of the Station.

Before leaving Bilbao on the 10th, the aneroid barometer was read off, when it stood at 30·019 in., temperature 71° Fahr. On arriving at Rivabellosa it indicated 28·473 in., the temperature being 65° Fahr. With these numbers I estimated the height to be 1481 feet above the ground floor of Mr. VIGNOLES' house at Bilbao, which is several feet above the mean sea-level.

Mr. PRESTON, however, was so kind as to connect my station by levelling with a normal point on the railway, and made its height to be 1572 feet 4 inches above the mean sea-level.

Recapitulation.

The geographical position of my observatory at Rivabellosa was, therefore,

Latitude N. 42° 42′, Longitude W. 11 min. 42·7 sec.,

and its height above the mean high-water mark 1572 feet 4 inches. Mr. STRUVE has communicated to me that the geodetic connexion of Rivabellosa and Pobes showed the geographical position of my observatory to be

Latitude N. 42° 43′ 24″, Longitude W. 11 min. 41·3 sec.

Lastly, I estimate the error of the mean-time chronometer, Frodsham No. 3094, July 18th, 0^h, to have been 4·6 seconds fast of Greenwich mean time, by assuming a progressive increase in its losing rate from July 16th to July 18th, and taking the mean between Dr. WINNECKE's and my own estimate for its error on July 16th.

After the return of the expedition, Mr. CARRINGTON kindly made some extensive calculations to admit of a direct comparison of my observed results with the demands of theory. To Mr. FARLEY I am also much indebted for special computations of the moon's position in respect of the sun's, in a form the most convenient for comparison with measurements hereafter to be mentioned.

Abstract of the Results of Mr. CARRINGTON's *Calculations for Rivabellosa.*

Assumed position of station:—

Geographical latitude	42° 42′
Longitude W. of Greenwich	$11^m\ 42^s{\cdot}7$.
Height above sea-level	1572 feet.

Whence the following elements:—

Geocentric latitude.	=42° 30′·5.
Log. distance from earth's centre . . .	9·9993676.

The true positions of the sun and moon are those of LE VERRIER's and HANSEN's

Tables, as derived from the Special Circular issued by the Superintendent of the Nautical Almanac.

For the totality the apparent positions were calculated for 3 h. 0 m. and 3 h. 5 m. Greenwich mean time, with the following results:—

Zenith distance of sun's centre	40° 33′.
Angle at sun between pole and zenith . . .	47° 59′.
Moon's semidiameter	16′ 33″·0.
Sun's semidiameter	15′ 44″·8.

Totality began at 3 h. 0 m. 37·4 s. at 101° 38′ on the sun.
Totality ended at 3 h. 4 m. 1·6 s. at 312° 56′ „
Direction of motion from 297° 17′ to 117° 17′ „

Relative motion during totality	92″·8.
Nearest approach of centres	13″·0.

Duration 3 min. 24·2 secs.

For the first contact the apparent positions were calculated for 1 h. 40 m., 1 h. 50 m., and 2 h. 0 m. Greenwich mean time, with the following results:—

Zenith distance of sun's centre	28° 49′.
Angle at sun between pole and zenith. . . .	35° 50′.
Moon's semidiameter	16′ 34″·6.

First contact at 1 h. 47 m. 56·0 s. at 296° 54′ on the sun.

Rate of approach of centres per minute . . .	24″·87.

For the last contact the apparent positions were calculated for 4 h. 0 m., 4 h. 10 m., and 4 h. 20 m. Greenwich mean time, with the following results:—

Zenith distance of sun's centre	52° 45′.
Angle at sun between pole and zenith	51° 36′.
Moon's semidiameter	16′ 30″·7.

Last contact at 4 h. 10 m. 15·2 s. at 117° 20′ on the sun.

Rate of retreat of centres per minute	29″·85.

The formulæ used in computing the moon's parallax and apparent semidiameter were

$$\theta = \text{Æ} \text{ of zen.} \qquad m = \frac{\varrho \cos\varphi' \sin p}{\cos\delta} \qquad n = \varrho\,\frac{\sin\varphi' \sin p}{\sin\gamma}$$

$$\alpha' - \alpha = -\frac{1}{\sin 1''}\left\{m \,.\, \sin\overline{\theta-\alpha} + \tfrac{1}{2}\, m^2 \sin 2 \,.\, \overline{\theta-\alpha} + \tfrac{1}{3}\, m^3 \sin 3 \,.\, \overline{\theta-\alpha}\right\}$$

$$\delta' - \delta = -\frac{1}{\sin 1''}\left\{n \,.\, \sin\overline{\gamma-\delta} + \tfrac{1}{2}\, n^2 \sin 2 \,.\, \overline{\gamma-\delta} + \tfrac{1}{3}\, n^3 \sin 3 \,.\, \overline{\gamma-\delta}\right\}$$

$$\tan\gamma = \tan\varphi' \,.\, \frac{\cos\frac{1}{2}\,.\,\overline{\alpha'-\alpha}}{\cos(\theta - \frac{1}{2}\overline{\alpha'+\alpha})}.$$

$$R' = R \,.\, \sin(\gamma - \delta') \,.\, \operatorname{cosec}(\gamma - \delta).$$

Mr. FARLEY'S *Elements of the Eclipse for Rivabellosa.*

The following calculations are based on the same latitude and longitude as those of Mr. CARRINGTON.

Greenwich mean time.	Apparent distance of ⊙ and ☾ centres.	Angle of line joining centres, N. towards E.	Aug^d. S. D. or Radius of ☾.	Ratio of Lunar to Solar radius.
d. h m	′ ″	° ′	′ ″	
July 18. 1 45	33 32·8	296 54	16 34·5	1·0526
1 55	29 22·0	296 54	16 34·4	1·0525
2 5	25 8·9	296 52	16 34·3	1·0524
2 15	20 53·0	296 47	16 34·1	1·0523
2 25	16 34·4	296 38	16 33·9	1·0521
2 35	12 12·2	296 23	16 33·7	1·0518
2 45	7 47·2	295 48	16 33·4	1·0515
2 55	3 19·3	293 40	16 33·1	1·0511
3 5	1 13·8	126 59	16 32·8	1·0508
3 15	5 48·2	119 20	16 32·5	1·0505
3 25	10 26·7	118 22	16 32·2	1·0502
3 35	15 9·1	117 57	16 31·9	1·0498
3 45	19 55·2	117 43	16 31·6	1·0495
3 55	24 45·0	117 32	16 31·3	1·0492
4 5	29 39·0	117 22	16 30·9	1·0488
4 15	34 37·2	117 14	16 30·5	1·0484

	h	m	sec.	
Time of first contact . . .	1	47	57	at 296° 54′ N. towards E.
middle . . .	3	2	20	duration of totality 3 min. 20 sec.
last contact . . .	4	10	15	at 117° 18′ N. towards E.

Nearest approach of centres 0′ 12″·7.

OBSERVATIONS OF THE ECLIPSE.

I. *Observations with the unassisted Eye, and with the Telescope.*

A splendid day on Sunday the 15th was succeeded by one of the grandest and most awful thunder-storms I have ever witnessed; and the 16th was cloudy, almost without intermission. The day previous to the eclipse had been completely overcast, with the exception of a short interval about noon; but even then the sun could only just be seen through a cloud somewhat thinner than those which obscured the rest of the heavens. The climate had therefore proved anything but propitious, and every interval of fine weather had to be diligently made use of for the adjustment of the instruments and the prosecution of observations. Fortunately an opportunity had presented itself on two days for practice in observing the sun with the Dallmeyer between 1 h. 30 min. and 4 P.M., and for special practice at about 3 o'clock. It was ascertained that during the progress of the eclipse the radius bars would have to be changed from one leg of the tripod-stand to the other, and arrangements were made to prevent the necessity for doing this during or near the period of totality.

To this instrument I had fitted an eyepiece of my own contrivance, which I described,

verbally, at one of the meetings of the Astronomical Society, and which was in consequence adopted by Mr. PRITCHARD. No account having been published of this appendage, and experience having proved its value in eclipse observations, I think it desirable to describe it here. It will be remembered that Mr. HODGSON some time ago proposed that a piece of polished glass should be used as a diagonal reflector in observing the sun; and "Hodgson's solar eyepiece" has been generally adopted, and is a most convenient and efficient instrument. It occurred to me, that if the glass reflector were made in the form of a parallelogram, of such dimensions that a moiety of its surface would suffice for the field of the telescope, one-half of the upper reflecting surface might be silvered and the other left plain, and that the addition of a suitable contrivance would enable the observer to draw into position the unsilvered or the silvered surface, according as either partial or total reflexion might be required. The silver film is so extremely thin that it in no way affects the focus, yet it is susceptible of the highest possible polish. It was not a convenient plan to silver only half the mirror; so, when the whole had been silvered *, one-half of the silver was neatly removed by means of a cloth, wetted with cyanide of potassium, strained over the forefinger. The roughened back of the reflector was freed from silver, and the plate then washed thoroughly with distilled water and allowed to dry. A little pad of wash-leather, well charged with dry rouge by rubbing it on a second piece of leather on which some rouge-powder had been placed, very soon removed the peach-like bloom from the silver surface, and produced a perfect polish.

The construction of the eyepiece will be readily understood by reference to the accompanying wood-engravings, wherein the same letter refers always to the same part.

Fig 1

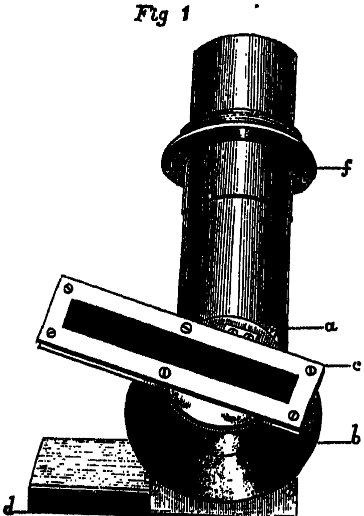


Fig 2

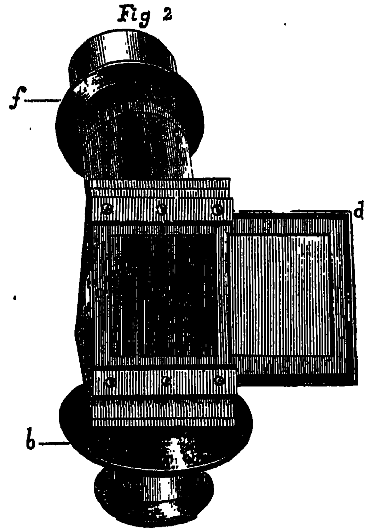


Fig 3

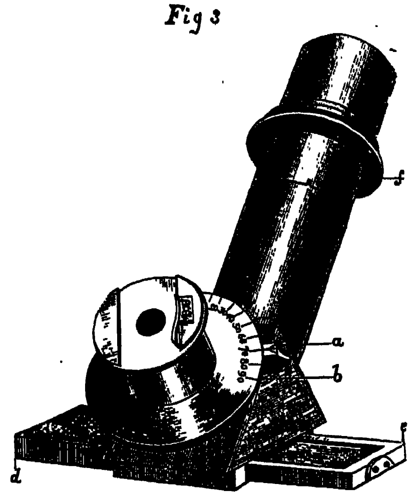
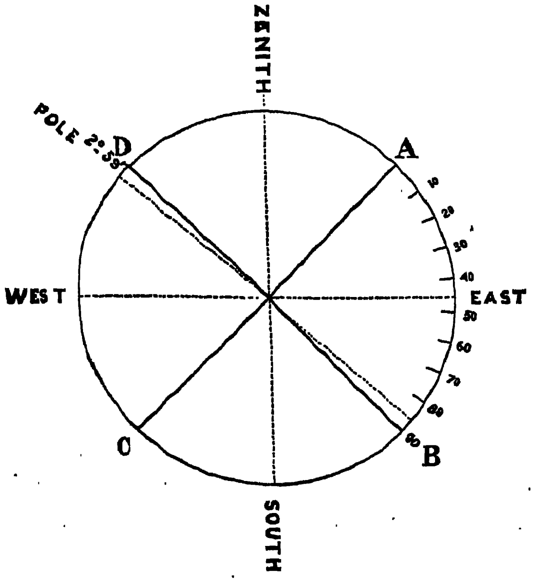


Fig. 1 is a front view, the plain glass reflector being in operation. Fig. 2 is a view of the under side, the plain glass being still in position for use. Fig. 3 shows the glass

* A method for silvering glass has been described by myself and Dr. MÜLLER in the 'Monthly Notices of the Astronomical Society,' vol. xix. p. 171.

reflector drawn out so as to place the silvered surface in the field. *f* is the socket-adapter, which screws into the telescope; it has a slit cut into it to receive a pin fixed on the sliding tube, the object of which is to keep the position-lines of the eyepiece, when once adjusted, in their proper position; *e* is the glass reflector, the half towards *d* being silvered, that towards *e* plain; *d* is a covering to protect the sliding reflector; *b* is a circle fixed to the body of the eyepiece, having one quadrant divided into nine spaces of 10° each; *a* is an index attached to a positive eyepiece, which can be moved by it through an arc of 90°; *c* is a graduated sun-shade, composed of a wedge of dark glass and another of white glass, reversed in position, so as to form, when combined, a parallel plate. This is held firmly in its place by means of a spring, shown in fig. 3, which, while it holds the shade firmly in any required position, also allows its instant removal at pleasure. The glass reflector *e*, as soon as the observer desires to use the silvered surface, can be drawn forward in a small fraction of a second, without disturbing any other part of the instrument.

In the focus of the positive eyepiece was fixed a piece of parallel glass on which were etched several lines; this micrometer-plate was carried round with the eyepiece whenever the index, *a* (figs. 1 & 3), was moved. A reference to Plate VI., which contains a fac-simile of my hand-drawings, and also a representation of the position-lines, will render clear the following explanation. Four principal lines on the glass plate formed a tangential square calculated to enclose exactly the moon's disk, which in fact it accomplished with great precision; four other lines surrounded the first square at the distance of exactly 1′ of arc; and a third series formed a third square at the same distance from the second. Joining the angles of the squares were two diagonal fainter lines, which served to measure angles of position, while the several squares served to measure distances. The angles of the tangential square may be designated A, B, C, D. As



soon as the axis of the telescope-stand had been adjusted in a vertical position by

means of screws affixed to the feet of the tripod-stand, and of a level attached to the vertical axis of the telescope, a distant mountain peak was made to run along one of the lines D A or C B by causing the telescope to turn on the vertical axis when the index of the eyepiece stood at zero; and the position of the whole eyepiece was regulated by means of a slight axial adjustment of the sliding tube until the line in question, and the course of the object horizontally across the field, showed an absolute coincidence. The diagonal lines D and A were then each 45° from the zenith; and the angle between the pole and the zenith at the period of totality being 47° 59′, the wire D, to the west of the zenith, was 2° 59′ east of the pole. This will readily be seen by the annexed diagram, which shows the apparent positions of the zenith and of the east, west, and south points in the field of the eyepiece, the zenith being represented in its natural position, but the east and west points reversed, right for left; so that, in referring any measurement to D, 2° 59′ must be added to reduce them to positions from the north point towards the east.

At last the eventful 18th of July arrived, and appeared hopelessly cloudy. The sky was watched with the most intense anxiety by us all; and I am free to confess that *my* nerves were in the most feverish state of agitation. Not the slightest break in the clouds or mist was visible until about 10 o'clock, when a streak of clear sky gave us the first faint gleam of hope. At noon the sky began to clear very generally, not so much by the clouds being carried off by the wind, as by their melting away in the air. An attempt was made to get an observation of the sun; but the clouds were so dense that it was only just as he was passing away from the field of the telescope that his following limb could be made out. Soon after this the clouds, which had been dissolving and gradually becoming thinner, disappeared all at once; and we had a magnificent sky, absolutely cloudless, except near the horizon. The heights towards the north in the direction of Pobes were perfectly free from mist; moreover we could discern through the telescope Mr. Bonomi and Mr. J. Beck on a low hill a few miles to the west of our station, and it gave us pleasure to know that at least two of the several parties were as fortunate as ourselves. The mists surrounded the higher peaks of the Pyrenees so pertinaciously that we expressed to each other great fears for our good friend Mr. Vignoles; for we were aware that he intended to carry out his plan of observations from one of the highest peaks, and we afterwards heard with the greatest regret that our apprehensions had been realized.

About twenty minutes before the commencement of the eclipse, an occurrence took place which very nearly brought all our labours to a calamitous termination. Mr. Preston had placed at our disposal his excellent and handy servant Juan, whom we had always found obliging, and very ingenious in expedients whenever any temporary arrangements had to be made. In order that he might have an opportunity of looking at the eclipse, I smoked a piece of glass for him with a wax lucifer-match, and he then, on his own account, prepared several pieces for the bystanders in a similar way. The demand soon increased so much, that he was scarcely able to keep pace with it, and at length became so excited that he threw away the matches in all directions without extinguishing them, and some, falling in the standing corn, set it on fire. The corn was very thin,

and fortunately the wind was blowing from the position of the fire towards the thrashing-floor; otherwise but a few minutes only could have elapsed before the conflagration would have assumed such dimensions as to be beyond the power of man to control. Happily, a few seconds after the occurrence, the crackling sound and the smell of burning straw drew my attention to the spot, and, water being at hand, the fire was got under before it had spread more than a few feet.

The Alcalde of Miranda had intimated to me, a few days before, that he was instructed to place at my disposal as many of the civic guard as I might think necessary to prevent interruption; but my experience of the consideration evinced by the Spaniards was such, that I replied that one or two would be quite sufficient. Shortly before the commencement of the eclipse, there arrived five mounted guards, who were of great use in preventing the crowd from encroaching on the thrashing-floor, which an excusable curiosity to watch our proceedings tempted them often to do. It is right to add that I could not persuade the guards to take any present whatever, their reply being that their orders on this head were imperative, and that, moreover, they had felt pleasure in being of service. When we were on the point of commencing our observations, about 200 persons had assembled round our observatory, and, although they conducted themselves perfectly well in other respects, their talking quite prevented my hearing the beats of the chronometer. They seemed to think that the eclipse could only be seen from my station; and it was with some difficulty that a number were persuaded to go to an adjoining height, whence the effects on the landscape and the progress of the shadow could really be better observed. I explained this, through the kindness of a gentleman from Miranda who spoke French, and who showed his faith in what I stated by leading the way. The Alcalde of Rivabellosa, CIVILO GUINEA, to whom I was indebted for facilitating my operations, explained to those who remained around the station the necessity for silence, and they thenceforth carried on their conversation in a tone which caused us no inconvenience. It is indeed impossible to speak too highly of the good feeling manifested throughout by the Spaniards of all grades, who endeavoured in every way to promote our objects.

Owing to my pocket chronometer having tripped, and become many minutes fast of Greenwich mean time, some confusion arose about the period of first contact, and a photograph, which it was intended to procure as close as possible to that event, was lost in consequence of the plates being prepared too soon, and none being ready when it actually took place. The error of the pocket chronometer was only discovered when it was too late, and it was then found to be faster than Frodsham 3094 by 8 min. 11 sec.

The first contact was observed at 1 h. 56 min. 55 beats.

	m	sec.	h	m	sec.
5 beats to 2 seconds			1	56	22
Error, fast of Frodsham	8	11			
Error, Frodsham fast of Greenwich mean time		4·4		8	15·4
Making the observed Greenwich mean time of first contact to be			1	48	6·6

	h	m	sec.
The occultation of the largest solar spot, which I call *c*, occurred at 2 h. 10 m. 125 beats . . . . =	2	10	50
Deducting the difference between the pocket Frodsham and Frodsham 3094		8	11
It gives	2	2	39

as the time by Frodsham 3094. This agrees within 0·5 second of the time noted by Mr. Beckley when a photograph of the phenomenon was taken in accordance with my signal, namely, 2 h. 2 m. 39·5 secs. Attention is called to the very exact accordance of the times recorded by myself and by Mr. Beckley, because I shall hereafter have to draw attention to certain conclusions which I have deduced, the soundness of which is dependent in part upon the epochs of the photographs having been accurately registered by Mr. Beckley.

After the occultation of the spot *c*, nothing worthy of record occurred until about 2 h. 12 m., when a cluster of clouds formed very rapidly and unexpectedly in the immediate neighbourhood of the sun, and completely put a stop to both optical and photographic observations. The clouds melted away about six minutes after they had formed, and thenceforward until the end of the eclipse all went on without interruption.

I had never before witnessed so great an obscuration of the sun as that presented by this eclipse many minutes even before the totality occurred, and I was particularly struck by the change of colour in the sky, which had been gradually losing its azure blue and assuming an indigo tint, while at the same time I remarked that the surrounding landscape was becoming tinged with a bronze hue, which to my mind suggested the idea that the light of the sun near the periphery is not only less intense than, but possibly different in quality from, that of the centre*. Spectrum experiments at future great eclipses, when the sun's crescent is reduced to an extremely narrow line, would set this question at rest, and might also have an important bearing on the line of investigations so ably inaugurated by Kirchhoff and Bunsen, into the composition of the sun's atmosphere. Another phenomenon could not fail to attract attention. When the sun's visible disk was reduced to a very narrow crescent, the shadows of all near objects became extremely black and sharply defined, whilst the lights, by contrast, assumed a peculiarly vivid intensity, the aspect of nature strongly recalling to mind the effects produced by the illumination of the electric light. Several minutes before the totality, the whole contour of the brown-looking lunar disk could be distinctly seen in the heavens.

Only a few brief seconds, unfortunately, could be spared from the telescope after the totality had actually commenced; but when I had once turned my eyes on the moon encircled by the glorious corona, then on the novel and grand spectacle presented by the surrounding landscape, and had taken a hurried look at the wonderful appearance

* In connexion with this remark, compare Sir John Herschel on the Chemical Rays of the Spectrum. Philosophical Transactions, 1840, Art. 82.

of the heavens, so unlike anything I had ever before witnessed, I was so completely enthralled, that I had to exercise the utmost self-control to tear myself away from a scene at once so impressive and magnificent, and it was with a feeling of regret that I turned aside to resume my self-imposed duties. I well remember that I wished I had not encumbered myself with apparatus, and I mentally registered a vow, that, if a future opportunity ever presented itself for my observing a total eclipse, I would give up all idea of making astronomical observations, and devote myself to that full enjoyment of the spectacle which can only be obtained by the mere gazer.

Although, possibly, not more than twenty seconds were devoted to observations with the unassisted eye, the phenomena remain strongly impressed on my memory, and at the time of writing this account, sixteen months after the event, I have it now pictured before me mentally, as vividly as if it had but just occurred. The darkness was not nearly so great as I had been led to expect from the accounts which I had read of former total eclipses; and although I had a lantern at hand, I did not require it, either in making my drawings or for reading the divisions of the micrometer quadrant on the eyepiece. The illumination was markedly distinct from that which occurs in nature on any other occasion, and certainly was greater than on the brightest moonlight night; and yet, at the time, the light appeared to me less than what I remembered of bright moonlight. It was only by subsequent trials, in endeavouring to make out details of the drawings which I had made of the phenomena, and to distinguish between colours under various circumstances of moonlight and twilight, that I was able to form a proper appreciation of the amount of light; and the best account I can give of it is, that it most resembles that degree of illumination which exists in a clear sky soon after sunset, when after having made out a first-magnitude star, other stars of less brilliancy can be discerned one after another. The light was good enough and sufficiently polychromatic to enable me to distinguish the colours of near objects; but those in the distance appeared to be illumined by the most unearthly hues.

Immediately surrounding the corona, the sky had an indigo tint, which extended to within about thirty or twenty-five degrees of the horizon, while lower down it appeared to me to be modified by a tinge of sepia. It became red as it approached the horizon, close to which, and just above the mountains, it was of a brilliant orange. The mountains appeared, by contrast, of an intensely dark yet brilliant blue. I saw two stars to the east of the sun, which by the aid of Mr. HIND's diagram I have since identified as Jupiter and Venus; but I had not time to search for more, or, most probably, I should have seen others. These planets, and also Castor, were made out by Messrs. ROBERT SWANSON, HARRY EDMONDS, and MATTHEWS, in the employ of Messrs. BRASSEY and Co., and were identified by them in my copy of Mr. HIND's diagram.

The effect of totality upon the bystanders was most remarkable. Until the beginning of totality, the murmur of the conversation of many tongues had filled the air; but then in a moment every voice was hushed, and the stillness was so sudden as to be perfectly startling; then the ear caught the sound of the village bells, which had been

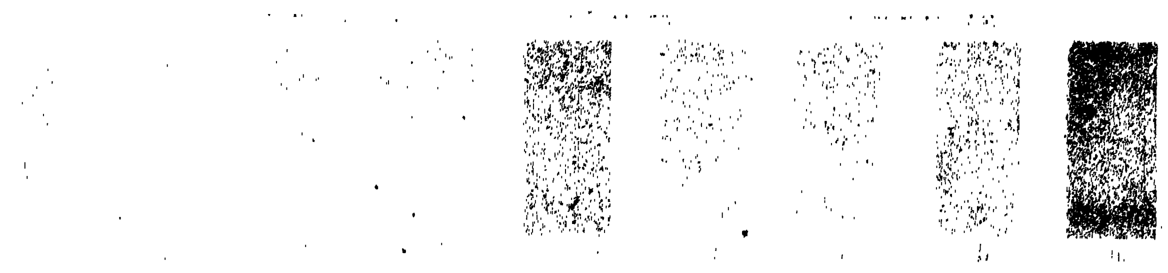
tolling unheeded during the eclipse, and this circumstance added much to the solemn grandeur of the occasion.

The time I could spare was far too short for any exact observations of the corona; however, I knew that Mr. Pritchard, Mr. Oom, Mr. Bonomi, and other observers intended to make special delineations and measurements of that phenomenon, and I therefore confined my attention to its general characteristics. It appeared to me to glow with a silvery-white light, softening off into a very irregular outline, while from its general boundary shot out several long streamers. It extended generally to about 0·7 or 0·8 of the moon's diameter beyond her periphery. Close to the moon, and reaching not further than 2′, the light was very brilliant, and several zones of gradations of brightness appeared to exist, but the very bright zones would all be comprised in a circle about 0·25 of the moon's diameter.

The observations just recited were made in the brief interval I could afford between the telescopic observations, which I will now proceed to describe. In order to facilitate my operations, I had prepared two diagrams exactly representing the appearance of the micrometer lines in the telescope, and, by chance, I had made the tangential square of such dimensions as to include a circle precisely 4 inches in diameter, which had been coloured to render it more readily distinguishable, and which represented the moon. Four inches happened to be almost exactly the diameter of the moon's disk on the screen of the heliograph; so that, later on, the photographs and the two drawings made during the totality, were readily compared by the superposition of each upon each.

On the diagrams I had painted fifteen streaks of various tints, some of which I believed might resemble the colour of the prominences, and some I knew would be useful as a contrast, to enable the eye to form a more correct judgment. The chromatic scale I here insert contains a selection of the tints painted round my diagram.

SCALE OF COLOURS WITH WHICH THE PROMINENCES WERE COMPARED.



Several minutes (probably five) before totality, I entirely removed the dark glass, and found that the sun's image might be looked at without the slightest inconvenience after reflexion by the plain glass. I could then see in the telescope, as I had shortly before seen with the naked eye, the whole of the lunar disk, which appeared of a deep sepia brown, nearly, but not quite, black, and, to my great surprise, I perceived a luminous prominence, about 20° to the west of the zenith, shining with great brilliancy, although, on account of the plain-glass surface being then in use, the greater part of its light

passed through the glass, and was therefore not reflected to the eye. I then, cautiously, but rather quickly, brought into action the silvered surface, and beheld with delight that the luminosity of the prominence, which I will call A*, was so great that there could be very little doubt of our obtaining the much wished-for photographic pictures.

I now watched carefully for the so-called Baily's Beads, but no such phenomena presented themselves,—at which, however, I felt no surprise, for I had always believed that they arose, in all probability, from the atmospheric disturbance of an image formed by a telescope wanting in perfect definition. The Dallmeyer I used was so perfect that I did not think I should see anything of the kind.

To the east of the zenith, about 20°, a floating cloud, quite detached from the moon's limb, and distant from it more than 0'·5, next attracted my attention. This cloud, which I will call C, appeared about 1'·5 long, and was inclined about 50° or 60° to the moon's limb. It had two curvatures, both convex on the edge most distant from the moon, and was decidedly of a rose tint, but of a much paler hue than the published accounts of previous eclipses had led me to expect. I compared the prominence carefully with my scale of tints, and found that it very nearly matched the colour marked *c*. It must therefore have been of a yellowish pink (approaching a salmon); for *c* on my chromatic scale was a mixture of carmine and cadmium yellow. This prominence (C) presented a great amount of detail, and reminded me of the aspect of a cirrus cloud glowing with the illumination of a setting sun. I should here remark that, in comparing my scale of colours with the luminous prominences, I depended on the general light of the heavens, and that I did not employ my lamp, which, I found, completely changed their appearance.

The prominence A was generally more brilliant, and did not seem to me to be so pink as the detached cloud; I could, moreover, detect a tinge of yellow in its brilliant light. It also showed considerable structure, appearing to consist of several streaks, curved inwards, while from the summit came two peach-coloured faint streamers, bending over in opposite directions downwards towards the moon's limb.

I paid most particular attention to the prominence A, because I knew from its position that it was critically placed for the observation of any change of position-angle in reference to the moon's centre; and I also remarked carefully the prominence C, and sketched all that I could make out by the most careful scrutiny. On comparing my drawings with the photographs, it will be perceived that a certain boomerang-like prominence in the photograph is wanting in my hand-drawings, and that there are also other prominences visible in the photograph which are not shown in the drawings. This is a curious circumstance, hereafter to be more particularly dwelt upon; but it is right to mention it here, because it affords me the opportunity of saying that, at all events, as regards the boomerang, I am certain that it was not visible in the telescope; for I observed so carefully in the neighbourhood of the floating cloud, that it is next to an impossibility that such an object could have escaped detection.

* See Index Map, Plate XV.

In the eastern quadrant (in reference to the zenith) a long line of prominences, extending over 70° on the moon's limb, was visible at the commencement of the totality, but before the end of totality it was covered by the lunar disk. This streak (which I call I) terminated in a hook, about 1'·5 high, bent upwards, and was *much indented on the concave side*, where it was in contact with the moon's edge. It was extremely brilliant, and, although it presented in parts a pink colour, was not uniformly so coloured, but to my eye had here and there a considerable admixture of yellowish white. In the first photograph of the totality is depicted a curious branching prominence, not unlike the fallen stump of a tree, which I did not observe, and therefore did not record in the sketches. I do not state so positively that this prominence was not visible, for this reason, that I did not pay such special attention to that part of the field, my eye being directed more particularly to the prominences A and C; but I have a strong impression that it was not visible. Just about the part where this would be, the corona appeared to me, in the telescope, to be particularly bright; but, besides a mere sheet of brilliant light, I saw nothing to delineate.

About half a minute after the commencement of totality, the progress of the moon uncovered, in the western quadrant (in reference to the zenith), a small peak, like that of a mountain, which I will call R. As the eclipse progressed, this prominence became more and more uncovered, and another smaller peak appeared, the whole contour reminding me somewhat of the hull and masts of a ship in full sail. Just before the reappearance of the sun this prominence reached apparently about 1'·5 beyond the moon's limb.

Extending from the southern base of this prominence, there came into view, about a minute before the end of totality, a long streak of prominences much *indented and irregular on the concave side*. This streak extended over fully 50° on the moon's limb, when it had been fully uncovered by her onward course. It was pretty generally of a decided rose tint. Just previously to the reappearance of the sun, I remarked a sort of carmine glow near that part of the moon's limb where the crescent of the sun was first re-formed.

Plate VI. is a most exact fac-simile of the two drawings, black representing white, which I made during the totality, and it is desirable that I should make a few remarks about them.

Figure 1 was begun, as nearly as I can recollect, about thirty seconds after the commencement of totality. As a preliminary step, the moon's disk was brought exactly within the tangential square, and the position of the prominence A, in respect of the line D, was noted first of all, and at once marked down on the left-hand diagram; the hook I was then referred to the line B, and the mountain R to the line D, the latter being registered with great care. The floating cloud and the other prominences were then filled in, possibly not quite so carefully. The details were next drawn in, black representing white, and the first diagram was completed as rapidly as possible, yet as faithfully as the short time at command would permit. I was aware, whilst so occupied,

that by the addition of detail after detail in the several prominences I was exaggerating their dimensions; but there was too little time to spare to rub out and commence anew.

When the first drawing was completed, about a minute and a half after the commencement of the totality, I looked away from the telescope in order to make the eye observations which I have already described, and before I resumed my work at the telescope an interval of half a minute may have elapsed, but certainly not more. The next thing I did was to measure the angular position of the prominence A; and after bringing the moon well into the tangential square, I moved the wire D through the arc necessary to bring it into contact with the side of that prominence nearest to D, which brought the index to an exact coincidence with one of the divisions on the quadrant; I noted down 10° for the angle moved through; but this is an evident error, for the angle was as nearly as possible 20°, which, added to 2° 59′, makes the position-angle of the western boundary of that prominence 22° 59′, from the north towards east, which is not far from its true position at that time.

Whilst measuring this prominence, I asked Mr. REYNOLDS, whose allotted task it was to develope the photographs after their exposure in the heliograph, whether anything could be seen on the first plate of the totality; and learning, with a thrill of intense pleasure, that the operation had completely succeeded, I made no further measurements, knowing full well that I should get them far better in the photographs.

Immediately after this, I commenced my second drawing, given in Plate VI., and noted down the position of the prominences A and R very exactly, by referring them to position-line D; and I then filled in the other details. As very little time remained for the completion of the drawing, I devoted my attention chiefly to the prominence R and a faint hooked prominence about 45° to the west of the position-line D, which did not imprint its image on the second photograph to the extent I should have expected from its dimensions in my sketch.

Between the completion of the first sketch and the commencement of the second, I estimate that there was an interval of about one minute, and that the second sketch was therefore commenced as nearly as possible 2½ minutes after the beginning of totality.

Thus, before commencing sketch No. 1, there elapsed,

	min.	sec.
From the beginning of total obscuration	0	30
To complete No. 1 sketch it required	1	0
Time consumed by eye observations, away from the telescope.	0	30
The measurement of prominence A occupied	0	30
Interval elapsed from the beginning of totality to the commencement of sketch No. 2	2	30

By placing a horn protractor on the original sketches, the following measurements were made:—

Protuberance.	Synonym.	Part measured.	Distance from position line D towards east, in degrees and decimals of a degree.	
			First drawing.	Second drawing.
A.	Cauliflower. Wheatsheaf.	First boundary, a * .	23°·0	20°·0
		Second boundary, a' .	28·0	24·5
		Middle	25·5	22·25
C.	Detached cloud.	First point, c . . .	58·7	49·0
		Last point, c' . . .	69·0	58·5
R.	Mountain peak.	First point, r' . . .	347·0	343·5

In order to reduce these measures to position angles from the North towards East, it is necessary to add to them 2° 59′, say 3°, which will give us—

	First drawing.	Second drawing.	Apparent angular motion in the interval.
A. Middle	28°·5	25°·25	3°·25
C. First point, c . .	61·7	52·0	9·7
R. First point, r' . .	350·0	346·5	3·5

As I before stated, the positions of A and R were laid down with great care; and it will be hereafter seen that their deviations from the positions given by measurements of the photograph are remarkably small. The measurement of all the details, however, do not agree so well, because the same care could not be devoted to the laying down of their positions.

These drawings show that there was a decided angular shifting of the luminous prominence A, and of others, in reference to the moon's centre; and taking into account the probable interval between the two drawings, namely two minutes, the amount of angular motion of A is a very near approximation to the angular change which must actually have occurred. As mentioned above, there is in the drawings an exaggeration of the dimensions of the prominences, which renders them unfit for the precise determination of the moon's actual progression in the line of motion during the period of totality; nevertheless they afford excellent evidence that there was, in fact, a covering and an uncovering of prominences, which, taken in connexion with the change in the position-angle of the protuberance A with reference to the moon's centre, can only be explained on the assumption that these extraordinary appendages belong to the sun, and not to the moon.

Furthermore, it would be quite possible to make out, with considerable although not with absolute accuracy, from these drawings, the direction of the moon's motion, and the extent to which the prominences first seen were obscured by the progress of the lunar disk, and others uncovered on the opposite side as the moon continued her course. For instance, it will be remarked on inspection, that the streak of prominences, almost 1′ in

* The letters refer to the index map, Plate XV.

height, depicted in the eastern quadrant of fig. 1, Plate VI., is almost entirely covered in fig. 2, and that the difference of position of the moon in the two pictures, when measured by a suitable scale, indicates a motion of about 50″ in the interval of two minutes which they include,—a result very near to the truth, for the actual progression in that period was 54″·5. The photographs, however, as will be hereafter seen, are so much better adapted for such determinations as these, that it is not worth while to dwell more upon the conclusions to be derived from the hand drawings.

In the two coloured drawings, Plates VII. and VIII., I have depicted the result of my telescopic observations; to facilitate my doing which at some future convenient time, I made a coloured sketch on the afternoon of the eclipse. This coloured sketch, the black-and-white drawings made at the telescope and shown in fac-simile in Plate VI., together with my photographs, which I have not hesitated to use to correct any errors of position or dimension in the sketches, have enabled me to give in these drawings what I believe to be a very truthful representation of the appearance of the prominences, immediately after the commencement and just before the end of totality. The corona I do not give as an absolutely true representation of that phenomenon, but as fairly resembling its general appearance. It has been derived from the photographs, so far as they show it.

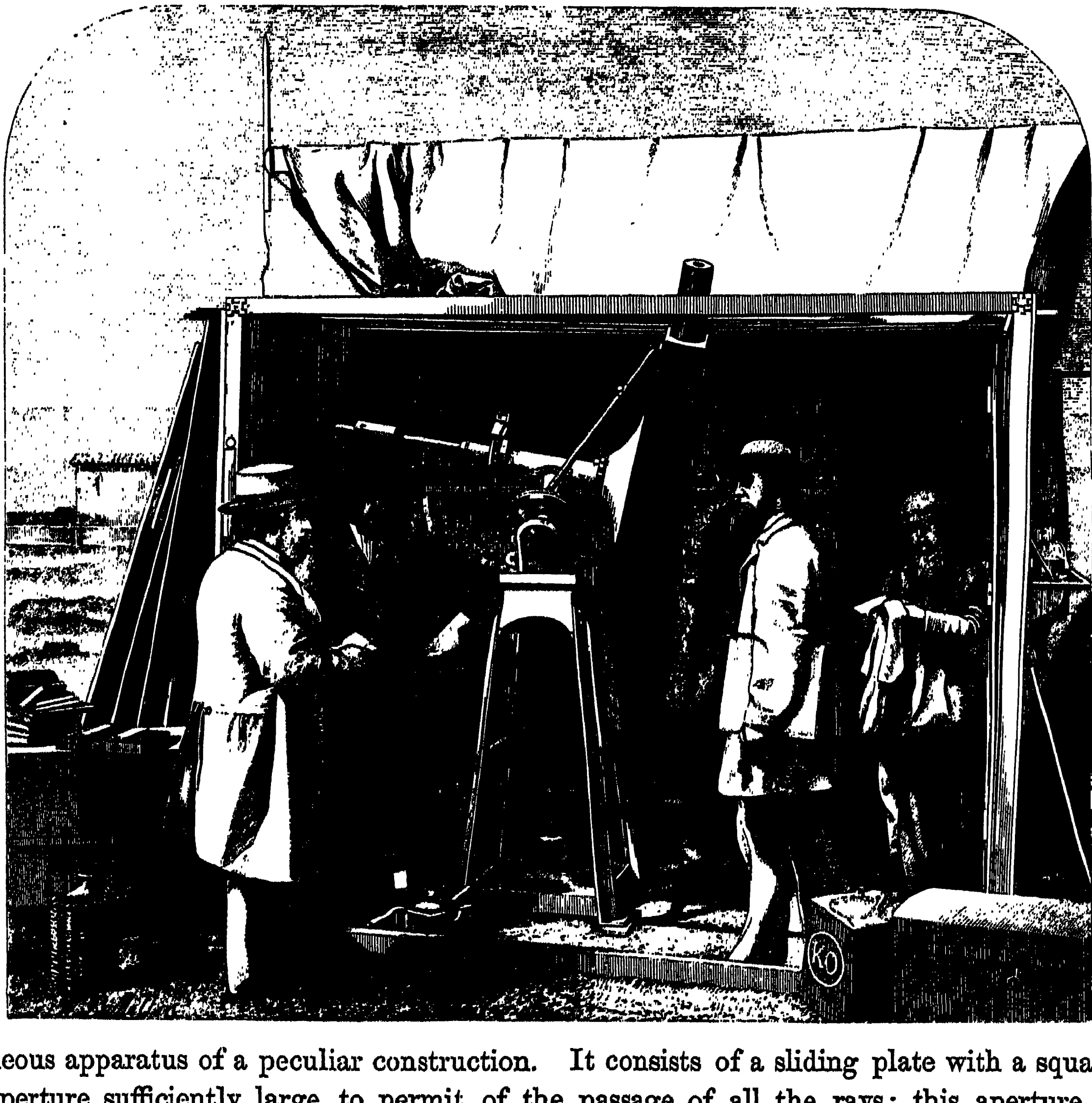
II. *Account of the Photographic Observations.*

The Kew heliograph, with which the photographs were obtained, is represented in the accompanying engraving *. It was devised by myself, for the special object of making photographs of the sun's disk, at the request of the Council of the Royal Society, in accordance with a recommendation to that effect by Sir JOHN HERSCHEL.

It has an equatorial mounting of the ordinary form, after the so-called German model, to which is attached a clock-work driver. The tube is square in section, and larger at the lower end than at the upper or object-glass end. The object-glass has 3·4 inches' clear aperture and 50 inches' focal length; the primary focal image of the sun at his mean distance is 0·466 inch in diameter; but before it is allowed to fall on the sensitive plate, it is enlarged to about 3·8 inches by means of an ordinary Huyghenian eyepiece. In the plane of the focus of the posterior lens of this eyepiece are attached two position-wires, which cross at right angles, and which were adjusted, approximately, into a position at an angle of 45° to a parallel of declination. The object-glass is so constructed as to ensure the coincidence of the chemical and visual foci; but this coincidence being somewhat disturbed by the Huyghenian secondary magnifier, the amount of adjustment required to effectuate the best chemical focus was ascertained very carefully by a series of experiments.

* The engraving was copied from a photograph taken at Rivabellosa. The front boards of the observatory were taken out in order that this might be done. Mr. DOWNES, who was charged with the preparation of the plates, is standing in the doorway leading to the developing room. Mr. REYNOLDS has a plate-holder ready to place in the heliograph, and Mr. BECKLEY is observing the time with the chronometer.

For sun-pictures, and the photographs of the several phases of the eclipse, the aperture of the object-glass was reduced to about 2 inches in diameter by means of a stop; but the light of the sun is so extremely powerful, that, even with this small aperture, combined with the enlargement of the primary image and its consequent reduction in intensity by 64 times, the shortest exposure possible with the ordinary means of uncovering and covering the object-glass would be far too long, and would give none but solarized pictures. For this reason the instrument has attached to it an instanta-



neous apparatus of a peculiar construction. It consists of a sliding plate with a square aperture sufficiently large to permit of the passage of all the rays; this aperture is fitted with a sliding piece, actuated by a screw which projects through and a few inches beyond the telescope-tube; by means of this screw the aperture may be completely opened, closed, or reduced to a slit of any required width; a divided scale being affixed to the screw for that purpose. The projecting screw connected with the slide is shown in the engraving, on the underside of the tube.

Previous to taking the picture, the sliding plate is drawn up just so high that the unperforated part of it completely shuts off the sun's image; it is held in this position by means of a small thread attached to it at one end and looped at the other, the loop being passed over a hook on the top of the tube; and the slide is pulled downwards, in opposition to the thread, by means of a spring of vulcanized caoutchouc attached to the inferior side of the tube. When the picture is about to be taken, the retaining thread is set on fire*, and the rectangular aperture, as soon as the sliding plate becomes released, flashes across the axis of the secondary object-glass—thus allowing the different parts of the sun's image to pass through it in succession, and to depict themselves one after another, after enlargement, on the collodion-plate. Although the time of exposure is so short as to be scarcely appreciable, yet it is necessary to regulate its duration; and it is therefore controlled by adjusting, 1st, the strength of the vulcanized caoutchouc spring; 2ndly, the width of the aperture. In practice, the opening is usually varied between one-twentieth and one-fortieth of an inch.

A number of plates, with ground rims and edges, were cleaned in London, so as to permit of their examination, and all defective ones were rejected; forty-eight selected plates were then numbered consecutively, and arranged in boxes marked very distinctly A, B, C, D, so as to ensure their being taken out in the proper order during the eclipse. The heliograph was furnished with three plate-holders, in order that no interruption might occur in the succession of the photographs; and as these were filled, they were placed in such a way that each plate was sure to be exposed in its numerical order. A few spare plates were also cleaned, and marked A, B, C, D, E, F, G, H, I, &c.

On the day previous to the eclipse the plates were again carefully cleaned, and replaced in their proper order in their respective boxes.

On the 18th the following plates were placed in the heliograph, and the time of taking each photograph noted by Mr. Beckley, with any requisite remarks. The time was observed with Frodsham No. 3094, whose error at Greenwich mean noon was, as already stated, fast of Greenwich mean time 4·6 seconds, and whose daily rate was losing 2·1 seconds. The exact time of depiction was ascertained by listening to the click which the instantaneous slide made in striking home upon a stop, when it had flashed across, in front of the secondary magnifier.

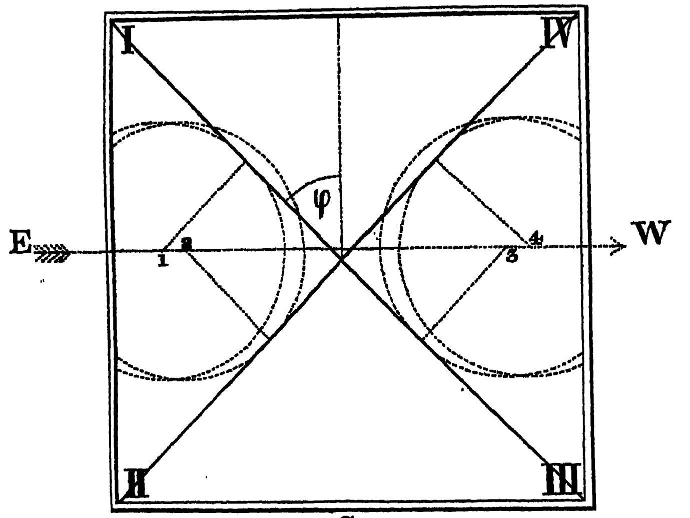
* Mr. Clark, who undertook this task, is represented in the engraving with a lighted taper in his hand.

No. or letter.	h m sec./2	Remarks.	No. or letter.	h m sec./2	Remarks.
1.	23 38 1	Through a cloud.	22.	2 48 60	Occultation of spot *b*.
2.	....	Spoiled.	23.	2 51 53	A solarized picture, in consequence of the full aperture being used and the instantaneous slide being detached.
3.	....	Spoiled.	24.	2 55 88	Id., the time uncertain.
4.	0 23 105		25.	....	Totality; time not noted.
A.	0 29 45		26.	....	Totality; time not noted.
B.	0 34 34		27.	....	Shaken by wind; time not noted; the instantaneous slide had not yet been replaced.
C.	0 42 24		28.	3 13 116	
D.	0 49 93		29.	3 17 32	Reappearance of spot *c*.
E.	1 3 23		30.	3 20 24	
F.	1 13 85		31.	3 24 35	
G.	1 25 45		32.	3 26 112	
H.	1 29 76		33.	3 34 12	
I.	1 41 76		34.	....	Spoiled.
5.	1 45 3		35.	3 37 48	
6.	1 47 96		36.	3 41 46	
7.	1 52 71	The first of the eclipse.	37.	3 44 4	
8.	1 56 15		38.	....	Forgot to uncover the plate.
9.	2 2 79	Occultation of spot *c*.	39.	3 51 116	Spot *a* uncovered completely.
10.	2 3 41		40.	....	Forgot to uncover the plate.
11.	2 7 21		41.	3 59 5	Reappearance of spot *b*.
12.	2 11 31		42.	4 2 96	
13.	....	Clouds.	43.	4 5 98	
14.	2 20 24		44.	4 10 75	
15.	2 22 97		45.	4 16 40	
16.	2 27 103				
17.	2 33 36				
18.	....	Spoiled.			
19.	2 36 43				
20.	2 41 55				
21.	2 46 46				

The diagram shows the appearance of the cross wires when projected on the glass screen. The image of the sun, being twice reversed, is finally depicted on the screen in its natural position, north being at the top, south at the bottom, east to the left hand, and west to the right hand. In the positive photographs of the eclipse, printed from the negatives, the pictures are likewise erect, and the points similarly situated. Calling the wires I., II., III., IV., I. would have approximately the position-angle of 45°, II. 135°, III. 225°, and IV. 315°. In the measurements, hereafter to be described, the several photographs were so placed on the measuring instrument as to cause its circle to read respectively one or other of these angles, according as either I., II., III., or IV. was employed in adjusting the photograph, the correction to the measured angles, necessitated by the deviation of that wire from its assumed position in reference to a parallel of declination, being subsequently applied.

The wires were found not to be absolutely at right angles.

	°	′
IV.— I. measured	89	59·3
I.— II.	89	52
II.—III.	90	8·7
III.—IV.	90	
	360	0



At 4^h 35^m, when the heliograph was pointed to the west of the meridian, observations were made to determine the deviation of the position-wires, from an angle of 45° to a parallel of declination, by the method described by Mr. CARRINGTON in the 'Monthly Notices' of the Astronomical Society, vol. xiv. p. 153; and the observations were repeated on July 19 at 11^h 55^m, when the heliograph was pointed east of the meridian.

July 18, 4^h 35^m, by Frodsham 3094 uncorrected.

The sun's limb made contacts with wires I. and III.

		sec.
at an interval of	. . . .	194
" "	. . . .	195
" "	. . . .	193
	Sum	582

and with wires II. and IV.

at an interval of	. . . .	188·5
" "	. . . .	191
" "	. . . .	188
		567·5

582 log $=3{\cdot}7649$

567·5 log $=3{\cdot}7540$

Angle of ϕ 45° 43′·5 log tan. $=0{\cdot}0109$

July 19, 11^h 55^m.

The sun's limb made contacts with wires I. and III.

		sec.
at an interval of	. . . .	189·5
" "	. . . .	188
	Sum	377·5

and with wires II. and IV.

at an interval of	193·5
„ „	193
Sum	386·5

whence angle $\varphi=44°\ 19'{\cdot}5$.

	h	min.			°	′
At	4	35	P.M.	$\varphi=$	45	43·5
At	11	55	A.M.	$\varphi=$	44	19·5
Interval	4	40	diff.	+	1	24·0
Interval . . . . . =		280		=+		84

$\frac{+84}{280}=+0'{\cdot}3$ the change of the angle φ in 1 minute.

	h	m	sec.
No. 6 photograph was taken at	1	47	48
Deducting	11	55	0
	1	52	48=112·8 min.

$112{\cdot}8\times0'{\cdot}3=34'$, $44°\ 19'{\cdot}5+34'=\ 4°\ 53'{\cdot}5$, the position of wire I. in reference to a circle of R.A. at the epoch of No. 6 photograph; hence the correction to be applied to the assumed position of 45° is $-6'{\cdot}5$.

With the foregoing data has been calculated the following Table of corrections, to be applied to the assumed position of the wires at the epochs of the several photographs.

No.	Correction to the wires.	No.	Correction to the wires.	No.	Correction to the wires.
6.	$-6'{\cdot}5$	20.	$+\ 9'{\cdot}5$	32.	$+23'{\cdot}2$
7.	−5·1	21.	+11·0	33.	+25·4
8.	−4·0	22.	+11·7	35.	+26·4
9.	−2·0	23.	+12·6	36.	+27·6
10.	−1·8	24.	+14·0	37.	+28·4
11.	−0·7	25.	+15·5	39.	+29·8
12.	+0·5	26.	+16·5	41.	+31·9
14.	+3·2	27.	+18	42.	+33·0
15.	+4·0	28.	+19·4	43.	+33·9
16.	+5·5	29.	+20·3	44.	+35·3
17.	+7·1	30.	+21·2	45.	+37·0
19.	+8·0	31.	+22·5		

In these corrections I have not taken into account a small error in the computed angle of φ, which arises in consequence of the wires not being at right angles; for, on examining them, I found that the heat of the sun had caused a curvature in one, and I could not, without much trouble, have ascertained the correction with precision. It was computed that it would not, however, amount in any case to more than $+2'$. My measurements of position-angle, hereinafter given, are moreover liable, from the difficulty of adjusting the photographs, to discordances to the like extent, as will be easily

conceived when it is stated that 2′ on the sun's limb do not occupy more than the space of $\frac{1}{1000}$th of an inch on the photographs obtained with the Kew heliograph.

At the moment of taking the photographs, the collodion was in a soft and moist condition, but subsequently, when the measurements were made, it had become dry. It became, therefore, not only a matter of interest, but of fundamental importance, to ascertain whether there had been any contraction of the collodion while drying, and, if so, whether the contraction had been uniform. Much care and attention were necessary in order to determine this point. By observing the positions of specks on the glass in respect of markings on a photograph while wet, it could be seen whether they retained their relative positions when the collodion had dried. The result, however, proved that there was no appreciable contraction, except in thickness, and that the collodion film did not become distorted, provided the rims of the glass plate had been well ground. I cannot show this more strikingly than by citing the measured radius of the sun on two photographs, namely, Nos. 6 and 45, and the measurement of the angles between the position-wires depicted on them. The radius of the sun No. 6 was found to be 1906·5, that of No. 45 1906·0 thousandths of an inch.

	Angle between IV. and I.	Angle between I. and II.	Angle between II. and III.	Angle between III. and IV.
No. 6	89° 59′·3	89° 52′	90° 8′·7	90° 0′
No. 45	90 2	89 53	90 6	89 58·5
Diff. 6—45 . .	−2·7	− 1	+ 2·7	+ 1·5

These differences, which are extremely small, do not exceed those obtained in measuring at different times the same photograph, and depend somewhat on the judgment exercised in causing the images of the position-wires to be bisected exactly by the wire of the microscope.

Photographs of the various phases of the partial eclipse, either previous to or after totality, exhibit a very curious phenomenon. The concave edge of the sun in immediate contiguity with the moon's limb, appears brighter than the other neighbouring parts of the crescent, while the convex limb of the sun bordered by the dark background of the sky, does not appear at all brighter than its proximate parts. This brightening of that part of the sun's disk which borders on the moon's limb, extends only for the space of a narrow line beyond the latter, but is remarkably conspicuous. As it cannot be accounted for by assuming the existence of a lunar atmosphere, it naturally excited a desire to trace out its cause. The Astronomer Royal, to whom I pointed out the fact, ascribed it to the effect of contrast, and I have subjected this hypothesis to the test of experiment in the following manner:—Having made some photographic prints of the sun's crescent on paper, which showed the appearance in a striking manner, I cut out about half of the crescent with sharp scissors, in such a way that the visible surface of the sun might be lifted up like a tongue, and replaced in its normal position within the background at pleasure; on smoothing the part so cut out, and causing it to occupy its original place,

the bright line was apparent, but it disappeared when the crescent was lifted up, and a sheet of white paper was interposed between it and the dark ground of the photograph. These phenomena occurred when the photograph was examined with the naked eye, with the aid of spectacles, or, from a short distance, with a sharply defining telescope by Ross. Viewed in either of these ways, the brightening was found to begin immediately beyond the edge of the white paper as it was introduced more or less under the crescent.

For the purpose of illustrating this paper on the occasion of its being read before the Society, I prepared a representation of one of the photographs of partial phase, 3 feet in diameter, in which, bearing in mind the well-known fact that there is on the solar disk a gradual diminution of the intensity of the light from the centre to the periphery, I carefully reduced the brightness of the solar crescent in due gradation towards the convex boundary. In the first instance the background was not painted in, and I expected that when it was completed a brightening would immediately occur. Such, however, was not the case.

On calling Professor STOKES's attention to this failure in producing the phenomenon of brightening by artistic means, he suggested that I should renew the attempt by using a real photograph of the sun and a dark disk for the moon*. On this plan I succeeded in making eclipse-pictures artificially, which showed the brightening very distinctly. From these experiments I am inclined to believe that Mr. AIRY's explanation is the true one, although it is a curious subjective fact that the parts possessing superior illumination exhibit to our perception an extremely bright line, bordering immediately on the dark limb of the moon, while the less bright parts towards the circumference present no such appearance, although they also are contrasted with the dark background.

In order to study other points connected with the photographs, I had made, on glass, some enlarged copies, in which the moon's disk was increased in some cases to 9 inches, in others to 13 inches in diameter. It was found that measurements could be made on these with considerable accuracy, by means of a graduated beam compass reading to thousandths of an inch, and I had proceeded to some extent in this way, when it occurred to me to have an instrument constructed expressly for measuring the original negatives. The study of the enlarged copies led, however, to a method of producing charts of the prominences with complete fidelity; and the plan will, I think, hereafter prove applicable to the production not only of astronomical, but also of other graphic representations derived from photographs. In order to carry out this method, a table had to be constructed with a square hole cut in it somewhat smaller than the glass positive to be worked upon; a recess surrounding the hole was made in the top of the table, just the size of the glass, and of a depth corresponding to the average thickness of the plates. Four spring clips served to hold the glass firmly in its seat. Parallel with

* For the lunar disk I employed photographic paper darkened to the same tint as the background of the solar photograph. These disks were in some cases neatly inserted in a circular hole in the solar picture, and in other cases pasted on it. In either case the surface was polished and made uniform by passing the picture through a rolling-press.

one side of the table were inserted two brass plates with long slots through which two screws worked. These screws passed through a straight edge, which could be adjusted so as to cause a right-angled drawing-triangle resting against it to assume any required position with respect to the image of the position-wires depicted on the photograph. A long glass mirror was attached to the frame of the table underneath the top, in such a way as to be adjustable to the angle best suited to reflect light through the transparent positive. In front of and above the table was placed an inclined screen formed of tissue paper, to diminish the direct light, a certain amount of which was required to show the position of the etching-point. Without the aid of this screen, the direct light would have been too powerful, and would have prevented the details of the transparent photograph from being seen by the light transmitted from below after reflexion from the mirror.

In the first place, the centre of the picture was found, and marked with a diamond point. A drawing-triangle, with one angle of 90° and two of 45°, was now placed over the photograph, with one of its sides resting against the adjustable straight edge, when its hypothenuse would coincide approximately in direction with the images of the wires. By adjusting the straight edge, the hypothenuse of the drawing-triangle was brought to exact coincidence with either of the wires, and the straight edge, against which it rested, was then (by means of the screws passing through it) clamped in position. By sliding the triangle along in contact with the straight edge, a line parallel with the wire was next set off passing through the centre, and marked slightly on the periphery of the picture by scratching with a diamond point through the collodion film. On taking in the beam-compasses a chord corresponding to 45° plus the known + or − error of the wires, a circle of right ascension, or a parallel of declination, could be made to pass through the centre, and, the points of its intersection with the lunar disk having been marked, any angles of position could be ascertained, by taking the chord between any part of a protuberance to be measured and the normal points thus set off.

If it were desired to produce an etching of any photograph, the outline of the protuberances or of the sun's disk and spots, or of the crescent of the sun, as the case might be, was traced very carefully with an etching-point through the collodion, with the aid of a lens. When this had been done, the plate was warmed by holding it before a bright clear fire, and a piece of composition, consisting of a mixture of paraffin and white wax, rubbed over it; the heat of the plate caused the waxy mixture to melt, and thus a very even, thin, and translucent etching-ground was laid on the glass. The outline was now traced a second time, in this instance through the wax, and a camel-hair pencil, wetted with liquid hydrofluoric acid, was rapidly run over the parts traced. In about a minute the acid was removed with blotting-paper, and the plate rinsed with water, and again dried with bibulous paper. When quite dry, the wax was melted by holding the plate before the fire, and wiped off with a cloth. If the etching proved satisfactory, it was again covered with an etching-ground, then centered on the circular dividing-engine, and degrees and subdivisions set off, starting from a normal point previously marked on

the plate. It was then put on the straight-line engine, and a scale of minutes and seconds of arc set off from the moon or the sun's periphery, in accordance with the previously calculated value in arc of subdivisions of an inch; both sets of division were then etched in the same way as the outline.

Sometimes, according to the position in which the photograph was taken*, the etching was performed at the back of the plate, to correspond with the previous tracing through the collodion on its face. In this case the collodion picture might be allowed to remain as "a witness" (as workmen call it) of the correctness of the etching. In other cases, if the original negative had been purposely turned over, so as to present the opposite face to the camera, then the etching was made through the collodion, which had to be removed before the subsequent operations about to be described were performed.

An etched glass plate, if filled with printing ink, could be made to give a print by placing india proof-paper over it, and, after superposing a sheet of glazed paper upon this, rubbing the latter carefully with a burnisher; but it would not be advisable to attempt to take many impressions in this way. However, by the well-known processes of electrotype, copper duplicates of the glass plate can be procured, which can be printed from in the ordinary copper-plate press; and as the glass plate is only used for furnishing the matrices, and is not injured thereby, the printing-plates may be procured without practical limit as to number. In this way Plates XIII., XIV., XV., XVI. and XVII. were obtained. The original glass plate of Plate XV. was, however, made in a somewhat different manner from the others. Originally, it was a photograph of the sun; after the outline of the sun and his spots had been etched, and the normal line marked thereon, the collodion was entirely removed, to permit of the plate being superposed, accurately, first over Plate XIII., and then over Plate XIV. Previously, however, Plate XV. was coated with the transparent etching-ground, and the luminous prominences depicted on Plate XIII. traced off, care being taken to ensure the parallelism of the normal line of one plate with that of the other, and internal contact between the peripheries of the sun and moon respectively. The same thing was done with Plate XIV., the prominences visible in the two pictures being placed in coincidence. In this way the pictures of the prominences could be made to assume their proper position around the sun's picture. In order to facilitate this operation, a positive picture had been previously taken with the enlarging-camera, from both the original totality negatives laid one over the other, and combined suitably together, so as to form in one picture a correct representation of the whole of the prominences. When the two totality pictures had been traced off on Plate XV., a line was drawn to join the two positions of the moon's centre, which had been set off from Plate XIII. and Plate XIV. respectively; this line was then prolonged to show the path of the moon's centre during the period of totality; lines were also drawn to join these positions of the moon's centre, and the sun's centre, and prolonged to the periphery of the sun, to indicate the points of disappearance and reappearance of the sun's limb. When etched, this plate was

* By placing the original negative in the copying-camera with the collodion film either turned towards the lens or away from it, the picture produced was either in its natural position or reversed right for left.

angularly divided concentrically with the sun, and a scale of minutes and seconds of arc etched, starting from the sun's limb, by which means the prominences were referred to the sun's centre, and their angles of position and heights above his periphery could be read off with a fair degree of accuracy.

In the three Plates, XIII., XIV. and XV., a wrong correction was, however, applied for the errors of the wires in determining the zero of the angular divisions, namely $+23'$ for both totality pictures, instead of $+15'\cdot5$ for the first totality picture and $+16'\cdot5$ for the second; so that in taking angles of position of the prominences, the readings on Plate XIII. must be corrected by applying the number $-7'\cdot5$; those on Plate XIV. by applying the correction $-6'\cdot5$, and those on Plate XV. by applying $-7'\cdot0$.

Moreover, a small error in determining the centre in Plate XIV. also interferes with the absolute correctness of the position-angles and of the heights of the prominences above the moon's periphery. Subsequently to this being etched, I discovered the fact that the centre should have been placed about $5''$ of linear space nearer 270°, in a direction from 90° to that point, and $4''$ nearer 360°. The angular positions of some of the principal prominences, determined by measurement of the original negatives, will be hereinafter given, so that no difficulty will be experienced in correcting the position of the other prominences as read off from the Plates. The prominences in these Plates are represented in their natural (erect) position, and this is also the case with the sun-spots in Plate XV.; the position-angles are laid down from North towards East. The North point (360°) is consequently at the top, the East point (90°) is on the left hand, the South point (180°) is at the bottom, and the West point (270°) on the right hand.

In order to facilitate reference to the prominences, I have designated them on Plate XV. by capital letters, commencing with the prominence situated at right angles to the path of the moon across the sun's disk, which I call A; and I then follow on towards the east with the other capital letters, the small letters being employed, either alone, or with one or more dashes, to mark the subordinate parts.

The three principal sun-spots are marked *a*, *b*, *c* in the order of increase of their several position-angles.

In Plates XIII. and XIV. the details were drawn in on the back of the glass plate, and the collodion pictures still remain intact; Plate XV. was drawn on the face of the enlarged positive, which had been taken intentionally in a reversed position, by reversing the original negative in the copying-camera. The correction in the position of the glass negative on account of its thickness was duly made; that is to say, the totality pictures having been copied with the collodion turned towards, and the sun-picture with the collodion turned from the lens, the collodion was in this way carried from the lens a quantity equal to the thickness of the glass plate. The holder supporting the original negative was therefore moved towards the lens a similar quantity, and the relative sizes of the pictures, as a matter of course, remained undisturbed.

Plate XV. will be found useful as an index map of the prominences, and will facilitate comparisons of the results obtained by the various astronomers who observed the eclipse. Moreover, the position of the sun's axis being given on it, an idea may be formed by